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FOREWORD

This Bulletin will be recognized by readers of publications of this Bureau as containing the type of material formerly published in *Herbage Reviews* and more recently in the Supplement to *Herbage Abstracts*. It is proposed to continue to publish collections of miscellaneous material in the form of Bulletins appearing at irregular intervals until such time as it is practicable to revive *Herbage Reviews*. *Herbage Abstracts* will continue to be issued in six parts per annum, of which five will be abstract issues and the sixth will contain the annual indexes.

The present Bulletin contains fourteen items on many aspects of the problems of grassland management and fodder production from different parts of the world. The items of greatest general interest will be the article by D. Meredith, of African Explosives and Industries, Ltd., giving his views on the future of pasture management in South Africa, the review of the pasture aspects of the survey of the dairy industry of New Zealand made by W. M. Hamilton (in which he discusses the possible future expansion of the industry and its relation to production and requirements in other parts of the world), and the statement of the crisis in the production and supply of seeds of herbage plants that has been experienced in the U.S.A., which has recently been the concern of a Committee appointed under the chairmanship of C. R. Enlow.

Other items dealing with South Africa and New Zealand concern the work that has been in progress for many years at Potchefstroom, which has recently been described in a special Bulletin compiled by A. R. Saunders, and also the trials of certain species of herbage plants at Lincoln, where a sub-station has been opened to test strains and varieties for conditions in the South Island of New Zealand, parallel to the trials already in progress for many years at Palmerston North.

The British items are a note on the scientific work of the late R. D. Williams by his colleague, Prof. T. J. Jenkin, to which has been added a bibliography of his published works on the breeding and genetics of *Trifolium* species ; also a review of the findings of the two special Committees appointed to consider the present condition and future prospects of the hill sheep farming industry in England and Wales, and Scotland respectively.

Canada is represented by a review of a recent report on prairie farm rehabilitation, in which a programme of regrassing ploughed-up and now abandoned land and the formation of " community pastures " of 15,000 to 20,000 acres in size are important aspects. A full translation of a Russian article on the irrigation of lucerne is included to indicate current views, practices and recommendations regarding this type of fodder production in that country.

Miscellaneous items include tabulated information on fodder trees in Madras (a subject on which a Joint Publication is now in preparation), reviews on vegetation and soil conservation in Brazil and Argentina, and notes on the agriculture of Szechwan and on the production of oil from subterranean clover.

TOWARDS A NATIONAL PASTORAL POLICY*

BY

D. MEREDITH,

African Explosives and Industries, Ltd.

Presidential Address to Section C of the South African Association for the Advancement of Science, read 28th June, 1943.

INTRODUCTION

During the past ten years there has been an increasing realization of the fact that the Union is not primarily a grain-producing country with large tracts of fertile soil only waiting to be exploited and that no very considerable expansion in the production of citrus or deciduous fruits can be expected as the areas in which it is possible to grow these crops on a commercial scale are strictly limited. Indeed it is now accepted by most agricultural authorities from our great leader Field-Marshal Smuts downwards, that South Africa is a pastoral country and that, as a consequence, agricultural policy should be based largely on the devopment and better utilization of pastoral resources. The Union possesses extensive areas of natural grazing or veld, rich in valuable grass species, and, notwithstanding the tendency of many people to stress the frequent occurrence of droughts, enjoys a fairly reliable rainfall of 20 inches per annum or more over the eastern half of the country. This address is concerned almost entirely with the possibility of realising the potentialities of these extensive grasslands.

THE VELD

The areas of veld or natural grazing in the Union of South Africa, disregarding provincial boundaries and excluding native reserves, may be divided into the following four categories :—

1. Arid area, receiving less than 10 inches rainfall per annum. This area, including most of the Karroo and the North-western Cape Province, amounts to 29 million morgen† and according to the 1936-37 agricultural census, supports a total of 1,037,000 livestocks units. In this paper, a method used by Clarke has been followed whereby numbers of livestock are calculated as mature livestock units. In making these calculations, allowance was first made for the age groups of the different classes of livestock and then all animals were converted into livestock units by taking horses and mules as ·75, donkeys as ·5 and sheep and goats as ·143 of a livestock unit.

These figures given in the 1936-37 census report have been used in preference to those of later reports, as there the age-groups of the classes of livestock are given, whereas in subsequent years only totals are given.

* Reprinted from the the South African Journal of Science, Vol. XL, pp. 37-56, November, 1943.

† 1 morgen=2·11654 acres.

2. Semi-arid area, receiving from 10 to 20 inches of rainfall per annum. This area, which includes Griqualand West, the Western half of the Free State and the Cape Midlands, comprises 27½ million morgen and in 1936-37 supported 3,084,000 livestock units.

3. Sub-humid area, receiving from 20 to 30 inches rainfall per annum. This area includes portion of the Northern Transvaal, the Transvaal and Free State high-veld areas, a portion of the Eastern Province and the South Western Cape and amounts to 24 million morgen, supporting in 1936-37, just over 5 million livestock units.

4. Humid area, receiving over 30 inches of rainfall per annum. In this area, which includes the Eastern mountain grassveld areas of the Transvaal, Natal and a portion of the Eastern Province, 11¾ million morgen, in 1936-37 supported over 3 million livestock units.

Total Livestock Population

European holdings in the better watered section of the Union, i.e., the sub-humid and humid areas thus comprise over 35½ million morgen, which support just under 8¼ million livestock units, including native stock on European farms. This gives an average carrying capacity of one livestock unit to 4·3 morgen of veld. Full allowance has been made for the actual areas under crops and forests and also for the land under dwellings and farm buildings. In the drier section of the Union, 56¾ million morgen support rather more than 4 million livestock units, giving an average carrying capacity of one livestock unit to 14 morgen of veld.

For the sake of convenience, from now on, I shall refer to the sub-humid and humid areas as the high-rainfall area, and the arid and semi-arid areas as the low-rainfall area.

Native Reserves. With regard to the reserves, it has not been possible to ascertain the exact areas, but according to Jones, the amount of land owned by natives at the time of the 1936 Act was 10,410,000 morgen. If we add the areas owned by natives in the released areas and in European areas, we get a total of 11,360,000 morgen. On this area there were maintained, according to the 1936-37 Census, some 4,072,000 livestock units. As the Census does not give the age-groups of livestock in the reserves, it was considered accurate enough for the purposes of this address, however, to assume that the age composition of native livestock was the same as that of European owned stock. The factors suggested by Clarke were therefore used in arriving at the above figure.

Although most of the native reserves fall in the high-rainfall area of the Union, there are several in the Northern Cape, in the districts of Mafeking, Kuruman, Taungs and surrounding regions. The total area of these and their livestock population are not known, but it was thought fair to assume that in the high-rainfall area of the Union, about four million livestock units were maintained on 11 million morgen From this area must be subtracted the land under cultivation and that covered by dwellings and other buildings.

This can hardly be less than one million morgen which means that the reserves were stocked at the rate of one livestock unit to 2½ morgen.

Combining these two sets of figures, we find that in the high-rainfall area of the Union, there are roughly 12¼ million livestock units on about 46 million morgen of veld. It will be readily appreciated, therefore, that the veld in the high-rainfall area is one of the most important agricultural assets, and it is probably fair to say that a substantial proportion of its enormous livestock population must obtain practically all its nutrient requirements from the natural grazing. It is true that the veld is helped in this task of sustaining its animal population by 138,000 morgen of teff (*Eragrostis tef*), 41,000 of other cultivated grasses, 13,000 of spineless cactus and saltbush, 102,000 of lucerne, as well as the aftermath grazing of crop lands, but in relation to the amount of feed required, this assistance is far too small to prevent heavy losses of liveweight in winter, and excessive stock losses through starvation in many parts, particularly in bad seasons. In fact, Hall has estimated that in 1934, our flocks and herds could have subsisted for only 40 days of the winter on all the supplementary feeds then available.

Treatment of the Veld

In view of the importance of our pastoral industries, it is pertinent to enquire, therefore, what treatment is meted out to our veld. The answer is that, except for very small areas under the control of a few enthusiasts, our veld, by and large, is given no treatment at all. Burning is done indiscriminately, grazing is badly controlled or not controlled at all, so that over or under-grazing are usually taking place and, so far removed are we from the idea of restoring or improving the fertility of our soils under veld, that those who suggest fertilizing veld, are regarded with suspicion. The result of our attitude towards the veld in general may be summarised in the words of the Industrial and Agricultural Requirements Commission, which states in the review of our agricultural resources contained in its third report that "at present, improper pasture management is resulting in an almost general deterioration of natural grazing, culminating in further denudation and moisture loss. Thus, what should be the most durable of the Union's natural resources is being dissipated extensively and at a cumulative rate."

If a national policy is to be evolved, it is imperative that problems of veld management should be investigated at more centres and in more of the distinctive veld types than is now the case, and when once new information is available, more effective machinery must be devised to ensure that these findings are put into practice by farmers. For instance, as far as burning of veld is concerned, much valuable information has been accumulated, but with few exceptions farmers who burn their veld are guided by little but whim or custom. Thus, it is not uncommon for farmers in many parts to burn veld in the growing season to provide fresh green grass for late summer grazing, although this has been shown to be a most deleterious practice. It is certainly less work than making hay in the summer or growing oats or other winter cereals for grazing, but its effect on the better species of veld grasses is ruinous.

Again, the mowing of veld in place of burning or as a valuable aid in veld management, needs emphasis in many areas. Admittedly there are large tracts of rocky and mountainous veld which can never be mown, and other extensive areas where scrub and bush would prevent mowing unless clearing or thinning were undertaken. Nevertheless, it must be one of the important points of a national pastoral policy, that mowing of veld be encouraged wherever possible for the control of grazing and conservation of the summer surplus of grass. This topic will be referred to later.

The spreading of thorn trees is allowed to proceed practically without check and is a serious matter in various parts of the country. Research into this problem is urgently needed and should be generously financed, in order that the proper balance between grasses, shrubs and trees may be determined, and methods of maintaining this balance evolved and put into practice. The area of veld involved is so great that thinning out the bush on a large scale might well be given attention when the post-war re-employment problem is being considered.

Agro-Economic and Regional Surveys

The management of grazing, as Irvine puts it, entails "adequate provision for the grazing animals at all seasons of the year, and at the same time the securing of stability or gradual improvement of pasturage." It will be readily admitted by most farmers that at certain times of the year, usually in early summer, there is more grazing available than the stock can consume, but for the rest of the year the animals can barely maintain their weight, and, in winter, unless supplementary feeding is resorted to, they steadily lose weight. In a bad season, or when spring rains are delayed, stock losses assume alarming proportions, mainly through starvation. Thus in the 1936-37 season, which was by no means a bad one, stock losses in the high-rainfall area alone totalled 890,000 livestock units or 7·27 per cent of the livestock population. In the European areas 495,000 livestock units or just under 6 per cent were lost, while in the reserves 355,000 units or 8·9 per cent were lost. In the low rainfall area total losses were 234,000 or 5·7 per cent of the total population. We should no longer look with equanimity on these heavy losses which occur year after year, even in good rainfall seasons.

It will be difficult to remedy this state of affairs over the country as a whole until the various types of veld have been mapped in greater detail and the potentialities of the different types have been assessed over a period of years.

In this connection, the Agro-economic survey of the Union, now being conducted by officers of the Division of Economics and Markets, is a step in the right direction, although the whole basis of their survey should be broadened by including animal and field husbandry officers, as well as pasture research officers in the team of investigators. This would result in a scientific appraisal of the physical resources of a region and there would be less emphasis on the financial aspect of current farming systems. Given this information, we should be able to make plans for the future of agriculture on a much more

reliable basis, for we would know more about the productive possibilities of the different parts of the country and consequently how to preserve and improve rather than waste our assets.

When once we have surveyed the whole country in this way, we shall have a better idea of the potential carrying capacity of various types of veld and, what is perhaps of even more importance, we shall be in a position to establish some controlling body or bodies to keep in touch with agricultural developments in various districts and, if need be, to take action to regulate grazing and stocking in the interests of the country as a whole.

In the United States of America, bodies of farmers have been formed to control erosion in certain areas and these bodies have been endowed with the necessary legal authority to enforce their decisions. In South Africa, such bodies might be farmers' associations in a typical veld area or public servants responsible to the Division of Soil and Veld Conservation, but, however constituted, they must have some power to enforce the decision of the majority of the farmers. Public opinion must be behind them in a firm resolve to prevent at all costs the destruction of our veld.

In formulating a national grazing policy, we must have the courage of our convictions and see to it that no distinction is made between veld belonging to Europeans and veld belonging to natives. In the long run, it will do us no good to maintain and preserve the veld under European control, while scattered widely over the country, native locations and even municipal areas and town lands are being steadily ruined. If it is admitted that the veld in European control in the high-rainfall area of the Union is deteriorating in many parts under a rate of stocking of 4·3 morgen per livestock unit, what must be happening in reserves where from 1·6 to 2 morgen are available per unit? On one small mission farm in Natal, less than half a morgen is available per unit.

The situation, admittedly, bristles with difficulties, not the least of which are the traditional Bantu outlook with regard to stock and the European belief that in some miraculous way denudation, destruction and erosion in reserves will have no harmful effect on European areas, but will, on the other hand, serve to augment the supply of native labour. Happily there are signs that both views are changing, and if this problem is tackled with courage and determination, the veld may yet be saved.

Grazing Control

From what has already been said, it should be clear that even when we have information about the areas and composition of the various veld types, upon which to base a national grazing policy, it will be essential to ensure much better utilization of the herbage than has been the case in the past.

Without some means of sub-dividing the grazing areas, the farmer cannot exercise the control essential to the efficient use of the veld. As far as South Africa is concerned, that means of sub-division and control is fencing. The grazing of veld types in smaller units; grazing at times best suited to

different veld types ; resting and protection of pastures—in fact, the intelligent management and efficient use of our grasslands depend ultimately on reliable stock-proof fencing.

In my opinion, the provision of fencing is one of the fundamentals of a national pastoral policy and the amount of materials required is so large that the question of establishing new factories and encouraging existing factories to increase the production of fencing materials might well be considered as a factor in a post-war re-employment programme.

It is difficult to estimate with reasonable accuracy the amount of fencing required by the country as a whole, but the following figures are submitted in the hope that some idea may be gained of the magnitude of the amount of material involved.

In the first place, trade and shipping returns for the period 1935 to 1939 show that our annual imports of fencing material ranged from 9,000 to 17,900 tons of barbed wire, 12,000 to 18,900 tons of plain fencing wire, 13,000 to 25,000 tons of standards and posts, and 3,000 to 5,250 tons of droppers. On the basis of four strands of wire in a fence and 700 yards of wire in a 100 lb. coil, the largest importation of barbed wire, namely 17,900 tons would allow the erection of over 35,000 miles of fencing. If all the plain fencing wire were used in the same way, our pre-war imports would have made possible the erection of up to 70,000 miles of fencing per annum. Of course, much of this wire was used in urban areas and for other than fencing purposes, so that in the immediate pre-war years, we probably erected something like 25,000 miles of fencing on farms every year.

Amount of Fencing Required on Farms

In order to obtain some idea of the fencing that would be required to subdivide farms according to improved methods of veld management, a rough calculation of the perimeters of farms with the minimum number of grazing camps in a given area has been made. The provinces of Natal and Transvaal were selected, as both fall within the high-rainfall area of the Union, and the average area of farms in each of the categories given in the 1936-37 Census was determined. Assuming all farms to be square, the length of the side for the average farm in each category was computed. Then allowing from 2 camps each for farms of from 5 to 20 morgen up to 18 for ranches of 10,000 morgen and over, it was estimated that the minimum fencing requirements for these two provinces would be some 498,000 miles.

Those portions of the Orange Free State and Cape provinces falling in the high-rainfall area are together probably less than half the area of the two provinces taken above and hence their fencing requirements on the same basis would be about 250,000 miles. The total for the high-rainfall area is therefore at least 750,000 miles of fencing. Now, if we assume very generously that half the farms in this area are already adequately fenced, and the remainder already have half the fencing they require, we would still need at least 187,000 miles of fencing in the high-rainfall area of the Union.

In the low-rainfall area of the Union, where farms are larger and, owing to the lower average carrying capacity, grazing is on a more extensive scale, the fencing requirements would be much lower than in the high-rainfall area of the Union. Furthermore, in certain sections, where sheep farming predominates, much jackal-proof fencing was erected prior to 1939. Nevertheless, this area probably requires as a minimum 500,000 miles of fencing and, making the same assumptions as previously, we arrive at a total of 125,000 miles for this area. In all, I estimate that European farms in the Union require at least a further 300,000 miles of fencing in order to insure some degree of control over the grazing. When eroded areas, which should be fenced until a vegetative cover is re-established, and the thousands of miles of dongas which should also be protected from stock, both in native and European areas are included it will be seen that our requirements of fencing from the point of view of veld conservation alone must be well over half a million miles, without making any allowances for material required for replacement of existing fences. Even if we accept the lower figure of 300,000 miles, it means approximately 150,000 tons of barbed wire, 230,000 tons of standards and posts, and 56,000 tons of droppers. These amounts are so large that I would suggest the adoption of a five-year plan in which from 50,000 to 60,000 miles of fencing could be erected per annum. The financing of such a plan could be effected either by means of fencing loans on attractive terms, or by means of a subsidy for approved fences erected within a specified period. No matter how the scheme is finally brought into being, our watchword must constantly be more fencing to save the veld. Along with more fencing must go education in pasture management for the camping off of the veld cannot by itself maintain or restore it.

Conserving and Improving the Fertility of Our Soils and Pastures

Although it is agreed by most people who have given the matter any thought that South Africa is not a rich country—agriculturally speaking—our soils, poor as they are, are nevertheless being exploited and, as far as the veld is concerned, the question of maintaining, let alone improving fertility, is seldom considered. Before going on to deal with the subject in more detail, it may be worth while to turn for a moment from the traditional outlook of the of the average South African farmer towards his veld, which is to look upon it as a gift of Nature, requiring nothing from him in return, and examine some modern trends with regard to fertilizers and soil fertility. This will serve to place the subject in its proper perspective.

The period 1941-42 marked two most interesting centenaries and, had it not been for the war, most agricultural workers and scientists would have freely acknowledged their importance.

In 1842 John Bennett Lawes took out a patent for the manufacture of superphosphate from mineral phosphates. The only source of phosphatic fertilizers prior to that time had been bones, either freshly ground or burnt. By 1862 the annual production of superphosphate in England had risen to

200,000 tons, and, by 1937, world production had reached a total of 16,868,000 tons, of which it was estimated 16,564,000 tons were actually used in that year.

The second is also a fertilizer centenary for, although sulphate of ammonia in the form of gasworks residues had been used in the liquid form in the first two decades of the 19th century, it was not until 1841 that the first authentic experiment with this product was recorded in Scotland. In 1849, it was reported that a considerable number of farmers were using sulphate of ammonia, and, by 1870, the production of this material in Great Britain had risen to 40,000 tons per annum. By 1900, the world use of nitrogen had raised the production of inorganic nitrogenous fertilizers such as sulphate of ammonia and nitrate of soda, to 300,000 tons per annum, and it has been estimated that by 1936 world consumption of nitrogenous fertilizers had risen to just over 12 million tons containing 2,214,000 tons of nitrogen.

In this connection a point of great importance is that in 1900, Chilean nitrate of soda accounted for 66·6 per cent of the inorganic nitrogen used, distillation of coal 33·4 per cent, while none was obtained from the air. By 1913 Chilian nitrate had dropped to 55·4 per cent of the total inorganic nitrogen used, coal had increased to 37·3 per cent, and 7·3 per cent was obtained from the air. By 1934, nitrate of soda had dropped to 6.9 per cent, coal to 18·6 per cent, and production from the air had gone up to 74·5 per cent of the total. The significance of this revolution in the production of inorganic nitrogenous fertilizers can hardly be over-emphasised, since it has been estimated that there are 20 million tons of nitrogen over every square mile of the earth's surface and hence the supply of the primary raw material is, practically speaking, inexhaustible. The technique of "fixing" atmospheric nitrogen having been developed, the dream of an age of plenty has now become a possibility.

Now, in view of the increasing world output and use of nitrogenous and other fertilizers, we may ask about the position of our veld and the pastoral industries it supports which, according to studies of the National Income, at present account for a net value of about £30,000,000 a year. The answer is, that of the fertility which is being withdrawn every year, very little is being put back by man. Neilson pointed out in 1931 that over a five-year period, the average annual loss to the veld in pastoral products exported, i.e., quite apart from those consumed locally and from all arable productions, was over 13,000 tons of nitrogen, 709 tons of phosphoric oxide and over 6,000 tons of potash. During this same period only 2,976 tons of nitrogen were imported, hardly a ton of which, it is safe to say, was applied to the veld. Our average annual imports of phosphoric oxide were 37,000 tons, and of potash 4,550 tons, but these fertilizer constituents were applied almost entirely to agricultural crops and not to natural pastures.

It may be claimed that, under natural conditions, there must have been an equilibrium in which the return of nutrients to the soil balanced the production of grasses, herbs, shrubs and trees. This is probably true, but conditions have changed, however, and can no longer be considered "natural." With modern ways of life there is now a constant flow of pastoral products away

from the land to the cities and even overseas. Although the manure and urine of animals return to the veld, and every year about 10 lb. of nitrogen per morgen come down in the rainfall, there is still a loss of nitrogen from the solid part of the manure, and the nitrogen and minerals in animal products such as meat, milk, cheese and wool are, for the most part, lost to the veld.

Lipman and Conybeare, in the United States of America, estimate there is a net annual loss in that country of 6·65 million tons of nitrogen, notwithstanding gains of 5·46 million tons due to symbiotic fixation, 4·37 million tons due to non-symbiotic fixation and 3·38 million tons from rainfall and irrigation. Very little information is available as to the amount of nitrogen fixed by thorn trees or other legumes in the veld in South Africa, nor do we know definitely what amount of nitrogen is gained by non-symbiotic fixation, so that it is not possible to present an accurate balance sheet with regard to this element. However, when we consider the amount of nitrogen in pastoral products exported prior to 1939, and the consumption of these products in the Union, it would probably not be very wide of the mark to estimate a loss to the veld of at least 100,000 tons of nitrogen a year. As a check on the accuracy of this estimate, we may note that Clarke has calculated a livestock unit weighing 1,120 lb. requires 136 lb. nitrogen per annum for maintenance alone, i.e., a total of some 833,000 tons of nitrogen for the livestock in the high-rainfall area of the Union. Subtracting from this the 230,000 tons that come down in the rainfall, we find that over 600,000 tons have to be provided by the grass from the soil. If only a quarter of the nitrogen taken in by stock is not returned in the form of manure and urine, then no less than 150,000 tons of nitrogen must be taken from the veld each year for livestock maintenance. The production of milk, meat, cheese and wool, the work of draft animals and the growth requirements of young stock must increase this amount considerably.

If this reflects the true position with regard to the veld, we may ask what can be done to restore the fertility of our soils under pastures. One of the first things that comes to mind is the encouragement of clovers and other edible legumes. In practice, however, this does not offer very much relief, as our soils lack phosphates and many of them are very acid. Our climate also, with its alternating wet and dry spells in the hot summer and a cold, dry winter, is not one under which clovers thrive. In moist low-lying areas, clovers might be encouraged, but in the aggregate the amount of nitrogen fixed by this means must remain small in relation to the total amount required to offset nitrogen losses.

We are thus forced to the conclusion that South Africa ought to come into line with other countries which now draw freely on the atmosphere for their nitrogenous fertilizer requirements. There is evidence that this country is awakening to the great need for nitrogen, for our imports of sulphate of ammonia, principally for fertilizers, have risen steadily from 1,376 tons in 1927 to over 15,000 tons in 1939. Nitrate of soda imports for agricultural purposes, although small, also increased over the same period. Up to 10,000 tons of bone fertilizers were also imported annually up to 1939. This is all

to the good, but it must be admitted that, although some fertilizers containing nitrogen may have been applied to improved pastures and fodder crops fed to stock, practically nothing has been applied to the veld.

This brings us to the main argument of this address which is that, unless we change radically our attitude with regard to the veld and consider it in every way as deserving of our attention as agricultural crop lands, and hence become willing to fertilize it liberally with nitrogenous fertilizers, we will be neglecting one of the most important factors in our internal economy—one, moreover which could put our pastoral industries on a sound footing, help materially in preventing erosion and enable us to feed all our people adequately.

Not only must we make good the losses from veld, but we must look upon the veld as a medium for the conversion of inorganic nitrogen into forms of protein required by livestock, for grasses are pre-eminently adapted to making use of large quantities of available nitrogen and converting it into nutrients

Investigations carried out by Hall and members of his staff since 1930 have shown that our veld responds, as do the grasslands of other countries, to applications of nitrogen. Considerations of time do not permit of this work being dealt with in detail, but some salient points may be given to indicate briefly the results that have been obtained. Thus the application of 600 lb. sulphate of ammonia per morgen in three dressings, along with phosphates and potash has, firstly, doubled the carrying capacity for the summer grazing season, six animals being maintained on four morgen as against three on four morgen receiving no fertilizer. The average annual liveweight gain over four seasons was increased from 131 lb. to 419 lb. per morgen. In addition, there was some surplus herbage produced on the fertilized veld which, though not consumed in summer, when mown, cured and stacked, was readily eaten in winter. This production was obtained on what would be considered poor, sour veld on an acid sandy loam deficient in phosphoric oxide, nitrogen and potash.

Hay yields from the same areas in a subsequent season showed that the unfertilized veld produced 1,716 lb. per morgen, whereas the fertilized veld produced 4,824 lb. containing 42 lb. nitrogen. The nitrogen content of the unfertilized hay was not determined, but even if it were as high as that of the fertilized grass, which is doubtful, the yield would have been only 15 lb. per morgen.

It is thus clear that the application of 600 lb. sulphate of ammonia per morgen increased the carrying capacity of poor veld from three animals per eight morgen for the whole year to six per eight morgen or up to three animals per four morgen. As the average carrying capacity for European farms in the high-rainfall area is one livestock unit per 4.3 morgen, it is obvious that wherever we can fertilize we can at least double the carrying capacity. Lest this be taken as a possible cause of overstocking, I hasten to add that in our fertilizer treatments the grass cover increased in density and, although there have been botanical changes such as an increase in *Eragrostis* species, production of weight increases has been maintained and surplus herbage ungrazed in summer

has been readily consumed in winter. Fertilizing the veld will thus help to prevent erosion by improving the grass cover and will not lead to overgrazing unless, of course, it is accompanied by mismanagement.

With regard to the potential use of nitrogenous fertilizers in South Africa, it is easy to speculate and arrive at astronomical figures involving millions of of tons. The farmer has to be convinced, however, that fertilizing will pay and the price of nitrogenous fertilizers will have to come down considerably before much progress can be made. Prior to 1939 the trend of prices for nitrogenous fertilizers was downwards all over the world, and it is to be hoped that before long, this trend will be in evidence again and the rate accelerated. More important even than the provision of cheap fencing, I look upon cheap nitrogen as the crucial factor in our pastoral economy.

So great are the benefits to be derived from the liberal use of nitrogenous fertilizers, that we must increase our consumption and put to good use all the by-product ammonia from coal that is being or may be produced in this country. After the war we should take advantage of increased production of nitrogenous fertilizers in other countries which will possibly be available at reduced prices. Eventually, as consumption increases, it may be necessary and desirable to undertake the production of synthetic nitrogenous fertilizers in South Africa. If every European farmer in the high-rainfall area of the Union could fertilize one-tenth of the area of his veld at the rate of 600 lb. per morgen, it would mean increasing the carrying capacity on 3½ million morgen from 800,000 to 1,700,000 livestock units, besides providing better grazing for the increased numbers. A programme of this nature would involve an amount of over a million tons of sulphate of ammonia or nitrochalk. As our fertilizer consumption mainly for arable crop production has reached a total of almost 400,000 tons per annum, including about 15,000 tons of inorganic nitrogenous fertilizers, the fertilizing of pastures may well bring about a trebling of the total amount consumed.

The use of nitrogenous fertilizers is not recommended in the low-rainfall area, except perhaps on irrigated lands, as farming is on too extensive a scale and the climate in general is such as to preclude economical returns from applications of fertilizers. It is essential, however, that a careful study should be made of the veld in this area so that it may be soundly managed and utilised in the best possible way. This might involve more fencing and an increased use of a complete rest for a season or more in rotation.

To give one-tenth of the native areas 600 lb. sulphate of ammonia or other nitrogenous fertilizer per morgen would require an amount of 300,000 tons per annum. In these areas it would do relatively more good than in European areas for the pastures in the reserves are consistently over-grazed and the grass is always short. In fact, it would be to the lasting benefit of the country as a whole if as great a proportion of the native reserves as possible could be fertilized, thereby increasing the density of the grass cover and greatly augmenting the production of foods of animal origin, especially milk, for the inhabitants of these areas.

Phosphates, Potash and Lime

With regard to dressings of phosphate, our experiments have shown that the average phosphoric oxide content of the herbage can be increased from 0·17 per cent to 0·29 per cent by means of annual applications of 400 lb. rock and superphosphate mixture per morgen, but the application of phosphatic fertilizers by themselves does not give returns of sufficient magnitude to make it profitable. An average content of 0·30 per cent P_2O_5 in the herbage is low compared with that found in other countries, but the animals in our experiments appear to have thrived and never to have consumed much phosphatic lick, although it was always available.

As pasture grasses will not make the best response to nitrogenous fertilizers unless some phosphate is applied, however, we should consider applying a phosphatic fertilizer, say, at least once in three years to the veld. This should make it unnecessary to feed bonemeal on such veld for the greater part of the growing season. As most farmers seem to find the practice of feeding bonemeal inconvenient, fertilizing the veld may prove to be an easier way of preventing phosphate deficiency. Fertilizing one-tenth of the veld, both native and European, in the high-rainfall area at the rate of 400 lb. superphosphate once in three years, which is about the minimum if worthwhile results are to be expected, would require the application of 320,000 tons annually.

With regard to potash, the evidence thus far obtained indicates that our soils are fairly well supplied with this fertilizer constituent, and on veld, at least, no significant increase is brought about by its use. For the time being, therefore, we may conclude that no potash need be applied to the veld

As far as lime is concerned we know that, although grasses will thrive on both acid and alkaline soils, they nevertheless do respond to lime applications on acid soils. We should keep in mind, therefore, the possibility that liming may be beneficial on many of our poor veld areas and that if sulphate of ammonia is used on a large scale in the future, applications of lime will be necessary from time to time to prevent the soil becoming unduly acid. Liming will also encourage the development of clovers where the climate is suitable.

It is not necessary at this stage to work out the amount of lime that might profitably be used, as the needs of our grasslands for nitrogen and phosphorus are relatively much greater than for lime and our immediate task is to see that these two plant food elements are supplied.

Compost

At the present time, when fertilizer supplies are limited, attention has been diverted to the provision of substitutes and we are now witnessing an intensive campaign having as its object the conservation of all organic wastes and their conversion into compost. This is a laudable objective, but there are a few points in connection with compost manufacture that should be kept in mind. It has been shown in numerous experiments, for instance, that in composting there is a loss of carbon as carbon dioxide and usually of nitrogen

as ammonia. The loss of nitrogen is usually estimated as being about 15 per cent, while that of carbon may rise to 50 per cent. Composting, therefore, does not add to the amount of nitrogen "in circulation" as it were, although it does reduce the waste of organic matter. A second point is that compost manufacture has a high labour requirement, particularly if it has to be turned one or more times. This will limit its usefulness, for our aim must be to reduce the labour requirements of our agricultural activities and replace hand labour wherever possible by machinery. Careful check must be kept on the costs of compost, as it seems easy to over-emphasise its valuable qualities and see in them something almost magical and lose sight of the fact that the plant nutrients it contains may be costing us more than they are worth.

A final point is that if compost is applied to permanent grasslands, the loss of nitrogen to the atmosphere and the resultant low recovery of nitrogen in the grazing or hay will make its use uneconomic. The application of compost to land being prepared for pastures or arable crops, where it can be ploughed in immediately, is, on the other hand, to be strongly recommended. The utilisation of waste straw, damaged hay, surplus grass and waste silage to enrich our arable lands and increase their yields is a sound farming principle provided that the cost can be kept within reasonable limits. In actual practice it will usually be found that when it comes to a question of applying 20 tons per morgen over an appreciable area, handling and transport problems become too difficult for the average farmer.

Supplementary Grazing

This brings us to the question of the treatment of our supplementary pastures, which were mentioned earlier in this address. A vigorous campaign for the popularising of what the census terms "other cultivated grasses" has been carried out for some 14 or 15 years, but the total of 41,500 morgen for the whole Union in 1936-37 is disappointingly small. This is probably due to several factors, of which the most important are : that many of the grasses recommended, particularly those of the woolly finger family (*Digitaria spp.*) set little or no viable seed, and hence pastures have to be planted from roots or stolons ; without adequate fertilizing or manuring, the yields, particularly after the first season, are often inferior to those given by the veld ; and, lastly, most introduced or cultivated grasses need careful management.

With regard to yield, our experiments have shown that, at the 600 lb. sulphate of ammonia to the morgen level, veld grasses can outyield a Rhodes grass and *Paspalum dilatatum* mixture on a poor sandy soil which has developed on granite, as regards both total yield and crude protein production. This should not be taken to mean that these cultivated grasses have no place in our pastoral policy, for most of them are very palatable, give good yields when adequately fertilized, and often give grazing at times when the veld has gone off or is dormant.

The fact that most cultivated grasses have a high fertility requirement is illustrared by the two following examples :—On one occasion a Rhodes grass and *Paspalum dilatatum* pasture was looking very poor and yellow in early

December, so some small blocks of plots were put down and given various amounts of sulphate of ammonia up to 2,000 lb. per morgen in a single dressing. Forty-two days later the plots were harvested and increased yields of dry matter and nitrogen, corresponding closely to the amounts of fertilizers applied, were recorded. Thus, the no extra nitrogen plot plot yielded 1,272 lb. dry matter per morgen, containing 13 lb. nitrogen, while the 2,000 lb. sulphate of ammonia dressing produced nearly five times the amount of dry matter containing nearly seven times as much nitrogen.

The other example of high potential yields on cultivated pastures came to light during the past season when a road between two blocks of camps was fertilized three times to encourage a grass cover and control erosion. Where contour banks discharged storm water in the camps, most prolific growth occurred. Investigation showed that the different mixtures of grasses were giving up to 17·3 and 19·5 tons dry matter per morgen in two cuts, containing up to 527 lb. nitrogen. In other words, when moisture is not a limiting factor and plant food is available, pastures on poor sandy soil can produce up to 3,200 lb. crude protein per morgen.

It is clear, therefore, that supplementary pastures could be fitted into a national pastoral policy, and, as they must always be established on land that can be worked, they could be grazed at certain times and mown for hay or ensilage at others. With adequate fertilizing, high yields of nutritious herbage could be expected.

Before leaving this section, a few words on the cultivation of teff may not be out of place. The popularity of this crop in the Union is somewhat difficult to understand, for it is an annual—is not particularly palatable, and is not a heavy yielder. The annual ploughing and working of the soil for this crop must inevitably result in erosion and soil depletion and a high cost of production. It should be part of our pastoral policy to encourage seed production of grasses such as Rhodes grass and *Paspalum dilatatum* so that good seed is available at reasonable rates. Farmers should then be urged to substitute for the annual teff crop, leys of three or four years of a mixture of these two grasses, which would provide high yields of good hay and also some grazing. At the end of three or four years, when the ley is ploughed up, the soil will be in a much better state than after a teff crop.

Irrigated Pastures

The potential yields of sown pastures already mentioned should make it clear that irrigation settlements could produce enormous quantities of hay or keep large numbers of stock when nitrogenous fertilizers become plentiful and cheap. If hay is produced, they would serve a most useful function by acting as sources of supplies of feed when other parts of the country are suffering from drought. The inclusion of intensively grazed and fertilized leys in the rotations of irrigation settlements will also have a most beneficial effect on the soils of these areas, especially as overseas experience indicates that pasture mixtures can withstand fairly high salt concentrations in the soil.

The Mechanization of Our Pastoral Industry

The proper development of our pastoral industries demands that all our livestock must be fed adequately throughout the year. If we accept this dictum, and also the fact that in most parts of the high-rainfall area, the grazing during autumn and winter and often in early spring is of low or reduced feeding value, then we must make provision for feeding our animals during these periods. The fact that so little feeding is done in winter and so little provision made for droughts, betokens a sublime faith in the reliability of the rainfall and an optimistic idea of the feeding value of our pastures in winter, which recurrent droughts and losses in condition should by now have dispelled.

One of the most serious obstacles to the development of our pastoral resources is our dependence on hand labour and our lack of suitable machinery for the essential operations of mowing and making hay and ensilage.

It is this dependence on hand labour that makes us keep such a large proportion of our population on the land—a proportion which reaches the extremely high figure of 66 per cent when natives in the reserves are classed as agriculturists. The only remedy for this, in my opinion, is to increase the efficiency of our agricultural operations, first of all by increasing the tempo of agriculture. This means that, for a start, we should critically examine the efficiency of ox traction and by using more horses and machinery, relegate the ox to the position for which it is best fitted, namely, the production of beef. Then we must use a much greater amount of machinery to increase the output per agricultural worker, while at the same time reducing the number of workers.

How far we are from possessing enough machinery for pastoral farming may be gauged from the following figures gathered from the 1936-37 Census. The enumeration of that year shows that in the Free State and Natal roughly one farmer in two has a mower and even fewer farmers have hay rakes. In the Cape Province and Transvaal one farmer in three has a mower and about one in four a hay rake. These figures are worked out on a basis of farms of 21 morgen and over, as it was considered these implements could not be used efficiently or would not be used at all on holdings of 20 morgen and under.

Altogether in the high-rainfall area of the Union there are roughly 58,000 holdings of 21 morgen or over, and on these in 1936-37 there were only 21,600 mowers and 17,000 hay rakes Thus considerably less than half our farmers could cut hay if they wanted to, except by hand with sickles, and less than one farmer in three could rake it, even if he cut the grass If holdings of from 6 to 20 morgen are included, the position is, of course, much worse.

Trade and shipping returns do not distinguish between binders, reapers and mowers, but they show that the largest number of these implements imported was in 1925 when the total reached 5,138. In the years prior to the war, up to 1939, the number imported annually was between 4,000 and 5,000, so that the number of mowers purchased each year by our farmers was probably below 4,000. This number of mowers will obviously not permit of a rapid expansion of hay and ensilage production.

It will be clear from what has already been said that a progressive programme will call for an enormous increase in the amounts of hay and ensilage made. Thus, to give 12¼ million livestock units 15 lb. of hay a day for four months would require over 11 million tons of hay. In this connection it is proposed that by far the greater part of these two products should come from the veld or introduced pastures and not from arable lands. It is usually claimed that our summer weather is unsuitable for hay-making, and so this operation is usually delayed until the grass has practically matured and its protein content has dropped considerably. The real reason is probably not the weather but the slowness of the process, for we must remember much good hay is made in England, Scandinavia, New Zealand and other countries with climates more humid than our own. However, if the weather is unfavourable and hay cannot be made, fairly good ensilage can be made from grass, provided some care is devoted to the process.

How far we are removed from an appreciation of the value of ensilage in pastoral agriculture is shown by the following figures. According to the 1936-37 Census, only 4,100 farmers out of about 50,000 in the high-rainfall area had pit or trench silos, which, after all, are nothing but excavations in the ground and are easy to excavate at a low cost and only 1,150 farmers or one in forty-three had a tower silo. The total amount of ensilage of all kinds made in the high-rainfall area in the same year was 182,000 tons or sufficient for a ration of 44 lb. a head for 8¼ million livestock units for just one day.

Our Machinery Requirements

If we are to cut enough hay and make enough ensilage to fed our livestock adequately, then it is clear we must increase the number of mowers in use. It has been estimated that for the proper control of veld, a mower is required for every 50 morgen. This would mean that for the same area of veld that is fertilized, namely one-tenth of each farm, 70,000 mowers would be required —that is, an increase of 49,000 on the present numbers. Actually, it would probably be found in practice that for the best results, every farmer with 50 morgen or more of mowable veld should have at least one mower. At this rate we could, with advantage, quadruple the number of mowers at present in use.

After the grass has been cut it has to be raked up into windrows and at present this process also is a very slow one. A great improvement in the speed of this operation could be effected by the use of side-delivery rakes drawn by horses or tractor. This implement moves faster than the rake and turns the swath over and leaves it in rows parallel to the direction of the cut. For drying hay, the side delivery rake is much superior to the ordinary type as the rows can be turned over and moved as often as desired. Moreover, the hay is left in a loose condition in the windrows, which facilitates curing.

When the hay has dried in the windrows, a saving in time and labour could be effected by loading it directly on to the wagon from the windrow by the use of the hay loader. Here again, the wagon would have to be drawn by horses or a tractor for the best results, as the pace of the ox is too slow and jerky for efficient loading.

When once the hay has been loaded on the wagon and has been brought to the shed or barn or to the place where it is to be stacked, time and labour could again be saved by the use of grabs and loading and stacking devices.

In a survey of the efficiency of different methods, it was found that three men loading and unloading a wagon by hand could stack 2·93 tons of hay per adult worker per diem. When the wagon was loaded with a loader and unloaded with a stacker, the work could be done by two men and a boy, and each adult worker stacked 5·87 tons in a day.

In the making of ensilage the grass does not have to be dried, and hence it can be raked and picked up as soon as possible after cutting. The process here can be speeded up by the use of side delivery rakes to put the crop into windrows, and sweeps to bring it to the silo or the wagon. Sweeps are widely used in New Zealand and Australia for rapid handling of large amounts of green grass. When grass is preserved as ensilage in a pit, or trench silo, it is usually unnecessary to cut it. All that is required is to bring it to the side of the pit or through the trench and offload it from the wagon. When it is put into a tower silo it will be necessary to use a cutter and blower.

Before concluding this section, the question of fertilizer spreaders must be given some attention, for if the veld is to be fertilized it cannot be done by hand. Nitrogenous fertilizers should be spread when the ground is moist, and hence the best and safest time to spread on a large scale is after a a good rain. At this time spreading should be rapid, and for the best results a spreader should be used. Horse-drawn spreaders would accelerate the process, while the use of a tractor would enable the ground to be covered with even greater speed. The ideal, however, is the type that has been developed in Australia, in which a spreading device is attached to or may even be a part of a vehicle, similar to a lorry, which is able to carry one or two tons of fertilizer. If the job is to be done, it will be necessary for each farmer to be able to spread at least 15 to 20 morgen a day with one spreader.

We know so little about the potentialities of these implements and labour-saving devices under South African conditions that it is difficult to estimate the actual number of hay rakes, loaders, sweeps, stackers and fertilizer spreaders required, but if every farmer on the 58,000 holdings in the high-rainfall area had one each of these implements, a great step forward in the control and utilisation of our veld would be possible. As a rough approximation, it would probably not be very wide of the mark to estimate that from 20,000 to 30,000 of each of the above items would be required before a really progressive pastoral policy could be put in motion.

The amount of machinery required in the native areas is difficult to assess, for in most parts there is little surplus grass to cut for hay. The need is great, however, and the example of Malietzies location quoted by Hall, where 12 mowers are used to cut hay for winter, could be multiplied many times to the advantage of the native people and their stock. It seems reasonable to estimate that the various native communities should be in possession of at least 1,000 mowers and 1,000 hayrakes, which would enable about 50,000 morgen or more of veld to be cut for hay. As the veld improves and the

native peoples progress, other implements, particularly fertilizer spreaders, could be obtained and used.

Considering the large numbers of implements required for the country as a whole, it appears a good case can be made out for the establishment of implement factories in the Union to cater not only for the needs of a pastoral industry based on an efficient utilisation of the natural herbage, but for arable agriculture as well. This would provide employment in the manufacturing industry, while the number of agricultural workers could be reduced as machinery becomes available for farm operations.

Conclusion

An attempt has been made in the time at my disposal to point out what a valuable asset we possess in our veld and yet how little has been done to maintain it or improve it. In considering measures for the protection and more efficient utilisation of the veld, we must first of all accept the fact that it is a national problem and not merely an agricultural problem in which urban dwellers may or may not be interested.

In discussing the main needs of our pastoral policy, namely, more research on pasture problems, more fencing, larger quantities of fertilizers and more machinery, all involving the expenditure of large sums of money, I fully realize that I am laying myself open to a charge of being unpractical or, at best, visionary. When it is considered, however, that in time of war we can tax ourselves to provide many millions for the defence of our country, surely we can plan to spend what would be a much smaller amount to protect and improve one of our most valuable assets. Furthermore, we should try to get a right perspective with regard to the whole field of agriculture, and realise that the first duty of the agricultural section of the population is to feed the rest of the population adequately without bringing about a deterioration of soil and veld.

When this change in outlook has been successfully accomplished, the establishing of the point of view that care of the veld and prevention of erosion are the concern of everyone would be automatic. Here again a great step forward will have been taken when the whole country realises that the prosperity of all in the long run is bound up with the condition of our veld. If the veld is allowed to deteriorate and soil erosion is not checked, the outlook is indeed dark and our future as a nation will be imperilled, for no nation can thrive or progress when its grasslands become eroded deserts or change to impenetrable scrub and its soils become windblown dust.

The programme outlined is an ambitious one, but it is not beyond our capabilities. It calls for careful planning and increased effort, but, if our veld is to play the part it is capable of playing in our agriculture, a programme of this nature is essential. The future of our country is very closely connected with the attitude we adopt towards our veld, which, we may be sure, will always repay in good measure the care and attention devoted to it.

FIELD EXPERIMENTS AT POTCHEFSTROOM

A report issued by the Union of South Africa, Department of Agriculture and Forestry (Science Bull. No. 14, 1942, by A. R. Saunders, pp. 138) comprises a summary of investigations conducted during the period 1903-40, at the Potchefstroom Experiment Station. The Station is situated (26° 44′ S. latitude and 27° 05′ longitude) at an altitude of approximately 4,430 ft. The surrounding country is flat, with scattered low hills, and the vegetation is typical grassveld with sporadic areas of thornbush. Crop production is limited to relatively small pockets of soil between hills or stony outcrops and there are no arable stretches comparable in extent with those of the chief maize area. The type of farming is greatly influenced by the proportion of arable land and ranges from an almost complete monoculture of maize to mixed farming in which cattle raising is the main enterprise. Irrigation is practised in several localities, especially on the banks of the Mooi River, where wheat and lucerne are the main crops and the soils, mostly of alluvial origin, are fairly deep and fertile. Rainfall is variable and has fluctuated between 34·60 ins. (1924-5) and 13·85 ins. (1932-3). Approximately 20 ins., or 85 per cent of the average falls during the six summer months, October to March. The effectiveness of this precipitation is greatly reduced by high evaporation and run-off.

Breeding Experiments

With regard to the breeding of crops it is maintained that South African agriculture is too young for natural selection to have had a chance of operating to the full, and its action is often being hindered by the constant introduction of new types which seldom come up to the expectations they have aroused overseas. The only indigenous crops of any importance are *Vigna sinensis* and *Sorghum* spp., both grain and forage types. Maize has received more attention than probably any other crop although scientific breeding experiments are of very recent date. From earlier importations of between two and three hundred varieties, not more than a dozen varieties are still grown. Selection work is in progress at the Potchefstroom Agricultural College and the Kroonstad Summer Cereal Station. In view of the need for types of high vegetative yield, an experiment has been devoted to the breeding of a strain especially suitable for ensilage and fodder purposes. Several crosses were, therefore, made between maize and *Euchlaena mexicana* and a type " Teomaize " has been evolved, but its vegetative potentialities require high soil fertility for full expression. Distribution of seed has therefore ceased and an attempt is being made to evolve a type with wider adaptation, although it is not regarded as possible to breed at any one station strains adapted to conditions of soil and climate in different parts of the country.

Breeding in *Sorghum* is largely concerned with resistance to *Striga lutea*, and types for ensilage are receiving attention.

Although *Glycine* was introduced into the northern provinces as early as 1903, it failed to establish itself until recently. There was lack of a market for the seed and the varieties tested shattered much of their seed at maturity.

In 1925 more than 300 varieties were imported from the Orient, U,S.A., and other parts of the world, and from this material a few individual plants were discovered which retained their seed for some period after maturity. A strain is regarded as non-shattering if not more than 1 per cent of the pods have dehisced when the plants are mature enough to harvest, and not more than 5 per cent a fortnight later. There are reasons for believing that the development of suitable types is only a matter of time ; many farmers are interested in the value of the crop for hay, but until farming methods are improved no phenomenal expansion in soybean production is anticipated.

Breeding work is also in progress with cowpea (*Vigna*), which is indigenous. The main objective is the development of types with upright growth habit to permit cutting with an ordinary mower.

The breeding of peanuts (*Arachis* spp.) is in progress, but so far none has been found which is agronomically superior to Virginia Bunch, although some types are more drought resistant and furnish a basis for improvement. There is indication that dormancy is closely associated with procumbent growth habit.

Since the Experiment Station at Pretoria exists specially for grass breeding, investigations at Potchefstroom have been limited to the improvement of *Chloris gayana* and the development of a perennial sorghum suitable for hay purposes. In 1940 a single outstanding strain of *C. gayana* was chosen for seed increase. The strain can still be improved but it constitutes an advance on the commercial type.

No perennial forms of hay sorghums other than *Sorghum halepense* have been cultivated. A similar perennial without underground stolons would be of value. Promising material has been selected from crossing Sudan grass with *Sorghum verticilliflorum* and with a natural hybrid from South West Africa.

Three new breeding experiments have been started with wheat, sunflowers and beans. With regard to wheat the aim is for a perennial winter grazing crop from crosses between wheat and *Agropyron*. The species of the latter employed are perennial, frost and drought-resistant grasses native to Russia.

The farmer who applies himself to intensive feeding of dairy cattle, pigs and poultry on a limited area requires a tuber-bearing sunflower, and experiments are in progress to breed this by crossing sunflower with artichokes.

Strain Trials

Varietal trials and cultivation measures for several crops are reported, notably, maize, sorghum, wheat, oats, etc., and various legumes (*Medicago*, *Arachis*, *Vigna*, *Glycine*, and field beans). A comparison is also made of yields of different crops for fodder purposes under different sowing and planting distances. The merits of 'nYati (*Pennisetum typhoideum*) are outstanding and experiments are being laid down to determine its value for grazing in comparison with other crops.

The merits of various legumes as hay crops have not yet been assessed, and in 1939-40 a preliminary experiment was carried out to compare soybeans, cowpeas, mungbeans and velvet beans. The last crop headed the list as regards yield, and was followed closely by New Era cowpeas. Tests were also made of yields of grass hay crops under different seeding rates. Optimum seeding rates naturally vary according to season, although it is not necessary to sow more than 25 lb. per morgen of Japanese Barnyard millet and Sudan grass and 10 lb. of teff, as tendency to lodging is aggravated by higher rates of seeding. Sudan grass and the millets are more reliable than teff in dry areas, Boer and Proso millets being particularly promising because of their fineness and ease of curing as compared with Sudan grass.

Pasture Investigations and Veld Management

At present much attention is being given to pasture grasses and there is a general belief that this is a new development. It is, however, a revival of an old scheme, for as early as 1904 some twenty-five species or varieties of grass were imported for trial at Potchefstroom. All the grasses except species of *Paspalum* quickly died out. In 1910 a collection of forty indigenous types was therefore made, and of these two have survived and proved useful, namely, *Chloris gayana* and *Cenchrus ciliaris*. With the advent of woolly finger grass (*Digitaria pentzii*), pasture investigations entered a new phase in 1928. Extensive plantings have been made from this grass for farm grazing, and it is a valuable supplement to the veld in times of scarcity. Experiments were laid down in 1933 to compare carrying capacity of veld, *Chloris gayana* and the following strains of finger grasses : Vryburg, Pretoria Large and Potchefstroom Large. *C. gayana* and the Potchefstroom strain of finger grass have proved outstanding in carrying capacity. As the main problem of the stock producer is that of providing winter feed, pastures were grazed in winter and summer during alternate years. " Wastage was greatest in the case of the finger grasses and the animals seemed to tire of their feed on these plots even when there was still a considerable amount of herbage left. In contrast the Rhodes Grass and veld plots were cleaned off completely, the animals appearing contented until they began to suffer from a shortage of feed.

"A somewhat surprising result was the relatively better return from the veld than during the summer of the year before. The sward had obviously benefited from the rest during the preceding summer and the vegetation appeared to be palatable, probably due to the variety of species. The Rhodes Grass on the other hand revealed unmistakable signs of degeneration. It had lost vigour and the sward was less dense than in the previous season.

" Differences in composition were not marked, although the finger grasses showed a slightly higher protein and phosphorus content than the veld."

Following the establishment of other species, ten plots were available for grazing in the winter of 1938, one of the driest seasons on record. Data are available of the carrying capacity (for the 1938 winter season and for the summer 1938-9) of veld, the Makarikari strain of *Panicum*, *Cenchrus ciliaris*, and the following strains of finger grasses, in addition to those mentioned

above : Middelburg, Steyn, Nelspruit, and Molopo. *C. ciliaris* grew by far the best under the drought conditions, but was rather unpalatable. Of the finger grasses the Middelburg and Nelspruit strains were definitely superior, though it should be remembered that they were 3 years younger than the Vryburg, Pretoria Large and Potchefstroom strains. Steyn's finger grass formed the densest sward of all but produced little top growth. It appeared admirably suited to grazing by sheep and shared with the Middelburg strain the virtue of early growth in spring.

" The only *Panicum* included grew well but the dry herbage was hard and coarse and the animals refused much of it. Veld grazing was poor, although little worse than that from some of the artificial pastures.

" An important fact disclosed by the analytical data is the low phosphorus content of the veld herbage and the *Panicum* strain. Protein contents were low throughout and particularly so in the case of veld and the Vryburg strain of finger grass."

Summer grazing, although only intermittent and for short periods, had an adverse effect on all grasses. An experiment to determine the effect of seasonal grazing on yield of finger grass showed that summer grazing gave the best returns, that after about 5 years the grass lost much of its vigour, became less productive, and species of *Aristida* and *Eragrostis* appeared in the sward. The finger grass lasted well and produced more than enough grazing to offset the high cost of establishment, but even such pastures should not be regarded as permanent. Experimental data under South African conditions regarding the value of a temporary ley in the crop rotation are lacking, but the ideal grass would seem to be a perennial hay type easily propagated by seed and capable of providing a certain amount of grazing. Few of the numerous types which have been tried meet these requirements, and Rhodes grass is the only one which occupies a position of prominence apart from some exotic species limited to certain areas of favourable rainfall.

" The question of artificial pastures *versus* natural veld is one largely of locality. In dry areas artificial pastures stand little chance of economic success, but in sections of the country with a high rainfall they have in many instances proved an asset of no small importance. Their establishment is, however, possible only on land which can be ploughed and as such land constitutes but a small fraction of the surface area of the country, artificial pastures can never make more than an insignificant contribution to our total grazing resources. In its broadest aspects, therefore, the task of providing better pasturage and of arresting the progress of erosion resolves itself into one of proper veld management rather than the establishment of artificial pastures."

Some account is presented in this Bulletin of veld management in the Union, certain aspects of which have been recorded elsewhere in the Herbage Publications (see *Herb. Abstr.* 12. Suppl. p. S. 40, 1942, and *Herb. Rev.* 7. 80-5. 1939). Saunders maintains that research in veld management should be directed not so much to finding what practice will give the highest yields of

beef or wool, but to determining what system will restore a good vegetal cover. Other benefits would follow this as a matter of course.

Chemical investigations have included study of effect of fertilizers and stage of growth on composition of the following grasses : *Panicum* Makarikari strain, *Cenchrus ciliaris*, and the finger grass strains, Vryburg, Pretoria Large, Potchefstroom, Middelburg, Steyn, Nelspruit, Molopo, Malmaniesoog, Pretoria Small, and Kuruman. " Differences in composition between grasses were generally small. The mean protein content of the dominant veld species, *Themeda triandra*, was disappointingly low, largely owing to a very rapid decline after the flowering stage. Kikuyu never attained a height of more than 4 inches and its protein content remained high until after frost. The same was true of its phosphorus content. In no instance did the fertilizers visibly improve the growth of the grass.

" Stage of development had little influence on ash and calcium contents, but the protein and phosphoric oxide fell rapidly as the grasses advanced in growth, the effect of frost being particularly severe in both cases.

" Fertilizer effects were almost negligible. The amounts of ash and calcium remained constant throughout, but superphosphate increased the phosphorus content slightly and ammonium sulphate the protein content. In this connexion, however, the fact should be borne in mind that the experiment was located on good virgin soil from which no marked response could in any case be anticipated."

Palatability Trials

In 1934-5 the grasses were subjected to a palatability test (with cattle) at the grazing, hay, and frosted stages. *Chloris gayana* was the most palatable at all stages, followed by the finger grass strains. Species of *Eragrostis* were palatable when young, but were almost totally refused by animals after they were frosted. The situation was reversed in the case of *Cenchrus ciliaris*, which was the least palatable of all at the grazing stage, but ranked high after frost. No effect on palatability from the fertilizer treatments was observed. Subsequent analyses showed that " Malmaniesoog finger grass was highest in protein and calcium, and the finger grasses generally contained more of these constituents than *Panicum* and *Cenchrus*. Advance in age of the grasses was accompanied by a sharp fall in the percentages of protein and phosphoric oxide. Ash and calcium contents were lowest at the hay stage. Nitrogen increased the protein content and superphosphate that of phosphorus more markedly than in 1923.

" A palatability test on the frosted grass revealed no noticeable differences and the experiment was discontinued in 1940 when all pasture and veld investigations were brought under the control of the Division of Soil and Veld Conservation."

A study of various grasses including species and/or strains of *Panicum* and *Digitaria* showed that at maturity the grasses contained on the average less than half the amount of protein they had at the grazing stage, the most

rapid decline occurring mostly in the case of the hay-type grasses, e.g. *Panicum maximum*, *P. planifolium*, the Makarikari strain of *Panicum*, and the Nelspruit and Ventersdorp strains of *Digitaria*.

* * * *

Following an account of various fertilizer trials, notably with maize, the publication records certain crop rotation experiments. These have mainly been based on maize under different fertilizer treatments and with legumes (ploughed in or cut for hay in some cases) incorporated with the cropping system.—M. HALL.

PASTURE DEVELOPMENT AND THE DAIRY INDUSTRY IN NEW ZEALAND

In his foreword to the " Survey of the Dairy Industry in New Zealand," by W. M. Hamilton (*N. Z. Journal of Science and Technology* 23. 257A-83A, 1942, 24. 1A-35A, 157A-85A, 223A-63A, 273A-302A, 1942/3), Dr. E. Marsden, Secretary of the Department of Scientific and Industrial Research, states that it has become desirable to look ahead to the period of reconstruction with a view to appropriate planning. It is helpful to study trends in each branch of primary production from the combined economic and technical points of view. These trends are vitally related to the practical application of the research carried out in the last decade which in many directions may well be as important and far-reaching in the national economy of New Zealand as, for example, the original introduction of refrigerated transport.

The series on the dairy industry by W. M. Hamilton has been prepared as an introduction to such studies. It is proposed, as opportunity permits, to follow with similar studies in various branches of industry important to New Zealand, particularly those affected by the many and far-reaching discoveries made during the past 25 years. In his own introduction, Hamilton states that his review aims to raise problems rather than to solve them, and uses past developments as a basis for forecasting the future. " It necessarily assumes a continuance of our present economic structure. The longer this war proceeds, the more likelihood is there of changes in the social fabric and the less valid becomes the approach adopted."

In a paper prepared for the Economic Conference in 1933, it was authoritatively stated that milk and milk products contribute more to farm income throughout the world than any other single agricultural product. More than half the total production is consumed as liquid milk, but milk has not entered to any extent into international trade. Milk surplus to local requirements is converted into butter, cheese, casein, and dried and condensed milk. Of these products, all of which enter into international trade, butter is by far the most important.

Large-scale international trade in dairy products is of relatively recent growth. For example, the production of butterfat in New Zealand has increased approximately tenfold during the past 40 years, under the stimulus of a number of factors, primarily of an economic nature. A major factor in the success of the New Zealand dairy industry has been the readiness with which technological advances have been incorporated into farming practice.

Among these technological advances, those concerned with the management of pastures have played a very important part, and permission has been obtained for the quotation in full of the section of Hamilton's review dealing with " Pasture Development."

Pastures as the Basis of Dairy Production

New Zealand is almost unique among dairying countries in relying almost wholly on pasture growth throughout the year for her dairy production. Such

a development has only been possible by reason of an equable climate and a well-distributed rainfall, but its success has been assured in no small measure by the development of a suitable management technique.

During the developmental phase of the dairy industry, cropping was carried out to a certain extent, in part as a preparation for sowing to grass, in part because farmers still clung to the traditional methods of the Old Country, and partly because a technique for utilizing the full potentialities of grassland had not been developed. Gradually, however, as it was found that deterioration in swards could not only be arrested but that marked improvement followed top-dressing with phosphates, the practice of growing supplementary crops declined, and was replaced by conservation of surplus spring and summer production as hay and silage. These trends are clearly shown in Fig. 1, the year 1915-16 being taken as base 100.

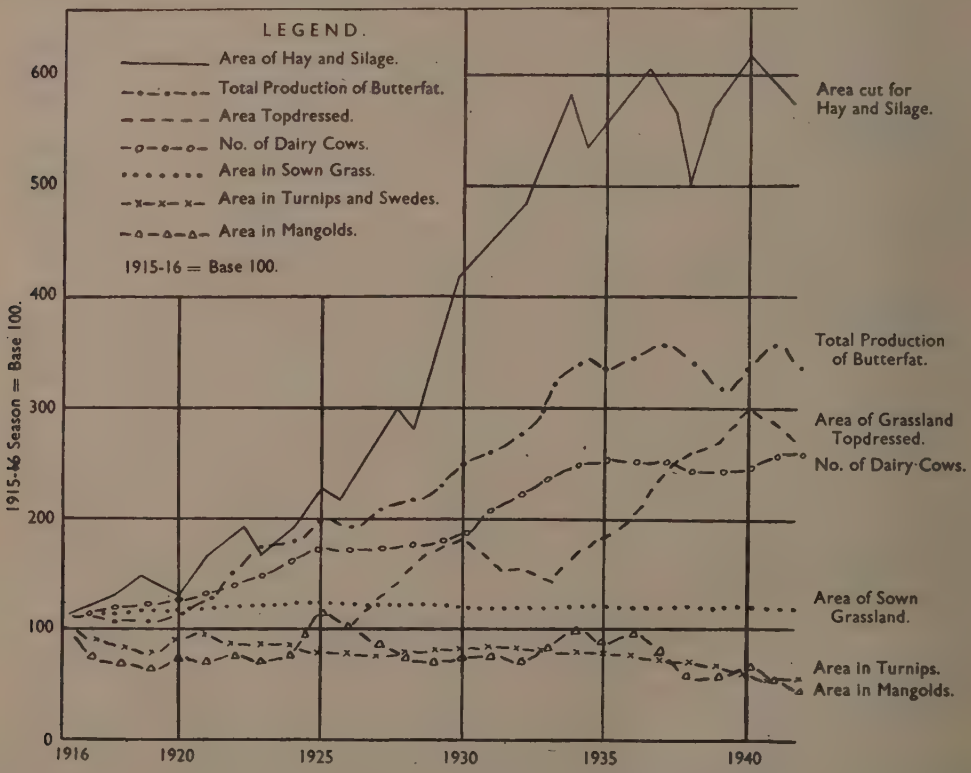

Fig. 1.—Total butterfat-production and numbers of dairy cows in relation to area of sown grass and areas of selected crops in the Dominion (1915-16 = base 100). Note that butterfat-production continued to increase in spite of a substantial fall in the area top-dressed following 1930, and that although the area top-dressed doubled between 1933 and 1940 there was no corresponding increase in production. Note also how the area saved for hay and silage in any year appears to foreshadow butterfat-production in the following season.

As shown in Fig. 1, in the 26 years since 1915-16, the total area in sown grass in the Dominion has increased by 20 per cent. During the same period the areas devoted to turnips and swedes and to mangels have contracted by 34 per cent and 41 per cent respectively, while the area in green fodder (rape and kale, etc.) has fluctuated considerably but is at present at the 1915-16 level. Owing to their tainting propensities, Brassicas have lost favour as supplements for milking-cows. On the other hand, the area of hay and silage saved has increased over five times. No data on top-dressing were collected until 1926, but since then the area treated has trebled. Cow numbers have increased by 160 per cent but sheep numbers by only 25 per cent, and conversion of cattle to sheep units indicates that our pastures have, over the period, increased in carrying-capacity by approximately 46 per cent. This is not the whole story, however, because stock numbers on hill and native pastures have been stationary or even declined somewhat, due to deterioration of pastures, and the increase has been almost wholly concentrated on the better-quality lowland pastures where top-dressing could be carried out.

Figure 1 also shows total production of butterfat in relation to area top-dressed and of hay and silage conserved. The two outstanding points are that in spite of a drop of 30 per cent in the area top-dressed during the depression, there was no corresponding fall in production—in fact, total butterfat-production rose steeply, while the area being top-dressed declined—and after the upward trend of top-dressing had been resumed in 1934 there was no corresponding rise in production. Secondly, it shows the very close correspondence between butterfat-production and the area saved for hay and silage. One would expect that most hay and silage would be saved in a good dairying year, but this is not the case—in fact, the hay and silage curve seems to foreshadow the trend of the following year's dairy production. It would seem as though the provision of adequate winter feed may be even more important than lavish top-dressing in increasing production, though, of course, the two (top-dressing and fodder conservation) are interrelated.

There are also interesting district differences to be observed, as shown in the table below, which takes the three main dairying areas and sets out selected data* for the years 1919-20, 1929-30, 1939-40. North of Auckland refers to the area north of Auckland City; South Auckland includes the remainder of the Auckland Province with the exception of the Gisborne-East Cape area; and Taranaki refers to the Taranaki Land District as at present constituted.

TABLE 1.—AGRICULTURAL AND PASTORAL PRODUCTION IN THE MAIN DAIRYING AREAS

	Sown Grass (Thousand Acres)	Supplementary Crops (Thousand Acres).	Area Hay and Silage, including Lucerne (Thousand Acres).	Area Top-dressed (Thousand Acres).	Number of Dairy Cows (Thousands).	Number of Cows per 1,000 Acres of Sown Grass.	Acres of Supplementary Crops per 1,000 Cows.	Acres Hay and Silage saved per 1,000 Cows	Percentage Sown Grass top-dressed	Average Production Butterfat per Cow under Test (Pounds).
1919-20.										
North of Auckland ...	1,149	8	1·5	...	79	69	105	19	...	180*
South Auckland ...	2,354	87	35·5	...	254	108	341	140	...	194*
Taranaki	1,051	37	22·1	...	145	138	258	153	...	230*
TOTAL ...	4,554	132	59·1	...	478	105	277	124	...	...
1929-30.										
North of Auckland ...	1,361	4	18	257	161	118	25	112	19	227
South of Auckland ...	2,655	42	187	1,115	513	193	82	364	42	247
Taranaki	1,038	22	60	331	198	191	111	303	33	267
TOTAL ...	5,054	68	265	1,703	872	173	78	304	34	...
1939-40.										
North of Auckland ...	1,449	4	41	451	265	183	15	155	31	237
South Auckland ...	2,857	36	269	1,583	749	262	48	360	56	256
Taranaki	949	13	84	424	240	253	54	350	45	276
TOTAL ...	5,255	53	394	2,458	1,254	239	42	314	47	...
Increase or decrease (per cent.) for the three districts over period 1920-40 ...	15	—60	565	44†	162	128	—85	153	38†	20

* Estimates. † Ten-year period.

* From "Statistics of Agricultural and Pastoral Production in the Dominion of New Zealand." Govt. Printer, Wellington. (Pub. annually.)

Taranaki was developed earlier than the other two districts and the area in sown grass has actually contracted by 102,000 acres in the last twenty years, due to deterioration of hill lands, while it has increased by 300,000 acres in North Auckland and 503,000 acres in South Auckland. The total sown grass in the three districts has increased by 15 per cent during the period, while cow numbers have increased by 162 per cent and the number of cows carried per 1,000 acres of sown grass by 128 per cent.

The area of hay and silage saved has increased markedly, particularly prior to 1930. The area saved per one thousand cows more than doubled in the ten years before 1930, but has been almost stationary over the last ten years. North Auckland still lags very markedly behind the other two districts in provision of hay and silage per cow, probably because it is in an earlier phase of development than the other two districts. Perhaps, too, the North Auckland farmer has been reluctant to relinquish the idea that paspalum makes good " natural hay " for wintering his stock and there has been considerable " wintering off " of herds on adjacent rough and semi-developed areas. The provision of supplementary crops (turnips and swedes, rape and kale, green feed, etc.) per one thousand cows has declined by 85 per cent. The smaller proportion of grassland top-dressed and the smaller area saved for hay and silage per cow in North Auckland is reflected in lower per-cow production.

Strain in Pasture Plants

Farmers had for many years recognized that pasture seeds from certain districts were of superior quality, but it was not till 1929 that these differences were officially recognized by the introduction of the " certification scheme." This provided a mechanism whereby seed crops were inspected during the growing season to assess their trueness to type, and identified the seed harvested from the area during the various stages of threshing, seed-cleaning, and sale. The scheme maintains strains of plants true to type once they are isolated, and serves a most valuable purpose by clearly identifying for the purchaser recognized useful strains. By its safeguards, it has fostered the growing of superior " certified " types of pasture plants for seed production in the arable areas and has been a powerful educative force. It does not by itself, however, improve the selected types ; this is the province of the plant-breeder.

Breeding and selection work has made considerable progress, in the first instance by indicating high-producing regional ecotypes such as Hawke's Bay ryegrass, and later by the selection of superior single plants, the testing of these by progeny and breeding tests, with eventual production of improved pedigree (bred) types. Particular attention has been paid to production, persistency, and the seasonal spread of production. These pedigree types are now providing a constant flow of superior-type material into the certification system, so that the standard of all " certified " types may be not only maintained but constantly improved.

There is not a great deal of published information in regard to the improved performance of certified or pedigree strains except for observations on single plant and broadcast plots at the Grasslands Division, Department of Scientific

and Industrial Research (Levy and Gorman, 1934, and Levy, 1932). These results show the marked superiority of " certified " over uncertified types of perennial ryegrass and white clover in respect of production, persistency, and seasonal spread. The results of trials reported by Levy and Gorman (1934) on white clover are shown in condensed form below and are typical of the results obtained with this and other species. Differences obtained in this type of trial, however, appear to be more marked than when these species are included in a pasture sward grazed by animals.

TABLE 2.—PRODUCTION FROM VARIOUS STRAINS OF WHITE CLOVER SOWN AS PURE SWARDS

(Green weights relative to New Zealand No. 1=100.)

Strain	Summer growth	Winter growth	Spring and Summer growth	Late Autumn growth
Station Selection Ac. 2070...	128	211	101	147
New Zealand No. 1 ...	100	100	100	100
Ordinary New Zealand ...	57	37	69	21
Kentish Wild White ...	47	26	65	15
Imported Dutch	42	20	39	0

A large-scale grazing trial of pedigree types of perennial ryegrass and white clover is at present being carried out in co-operation with Massey College, but results are not yet available and adequate quantitative data on the performance of " certified " types under field conditions are lacking.

In view of the high performance of certified types shown by the above figures, it is surprising to find that they have not been more widely used by farmers. In the period 1931-40, 450,000 acres of virgin land and 667,000 acres previously cultivated were sown to pasture in North Auckland, Auckland, and Taranaki Land Districts. An assumption that " certified " perennial ryegrass was used for sowing in the same proportions as it bore to the total harvest in the previous season would mean that some 258,400 acres have been sown with " certified " ryegrass, and that at the present time 5 per cent of the total area of sown grass in these districts has been laid down with " certified " seed. It should be noted that the above figures of area sown include hill country, since no distinction is made in available statistics, but owing to its cost it is doubtful whether " certified " seed has been sown to any extent in surface sowings. One is forced to the conclusion that to date the improved strains of pasture plants available have made little direct contribution to increased carrying-capacity in the dairying districts and at the present rate of replacement of pastures (approximately 1·2 per cent per annum) it will take many years to obtain measurable benefits. Connell (1938) arrived at the same conclusion in 1938 by a different method, and calculated that, if all the certified perennial ryegrass seed produced were used for resowing our dairying and fat-lamb country at the rate of 1 bushel per acre, it would take a period of

35 to 40 years to sow the area involved. " The corresponding periods for cocksfoot, white clover, and red clover are very substantially greater, those for cocksfoot, for instance, being 110 years to 120 years and for the others greater still." It is clear that the achievement up to date is not impressive. It should be added, however, that the " certification scheme," in addition to its direct benefits, has helped to make farmers " strain " conscious and has favourably influenced the general quality of seeds even outside the scheme. Also, before the certification scheme was inaugurated many pastures were sown with good types of ryegrass from Poverty Bay and Hawke's Bay and these have responded well to top-dressing and improved systems of management.

Breeding and selection work to date has been largely concentrated on high-fertility-demanding species such as perennial ryegrass and white clover, which may be held to be better suited to sheep than to dairy pastures. White clover causes bloat in cattle and undesirable flavours in cream, while ryegrass appears to be associated with facial eczema. Coarser grasses such as cocksfoot and paspalum are generally regarded as better suited for dairy stock, but definite experimental evidence is lacking, although trials are in progress at the Dairy Research Institute.

The improvements made so far have been mainly a process of taking up the slack—using the best naturally occurring ecotypes to replace inferior strains. The potentialities of this method will in due course be exhausted, and it seems probable that, before further progress can then be made, additional fundamental knowledge of the breeding material will be necessary. To date we have little other than empirical knowledge of the response of the pasture plant to its environment. It is rather striking that the best selected European strains of ryegrass and white clover do not compare favourably under our conditions with local selections. There is a suspicion also that the reverse may be true when our selections are grown in Northern Europe. A knowledge of how our strains respond to variations in length-of-day, temperature, level of fertility, etc., may be exceedingly important if we desire to increase our export of pasture seeds to conditions other than those in which they were selected, and a lack of such knowledge may eventually hamper further development of superior strains for our own conditions. The solution of the facial-eczema problem might also be expedited by a fuller knowledge of the physiology as well as the biochemistry of our pasture species, and the development of research in plant physiology would seem to be a logical extension of present breeding-work.

Pasture Surveys

It was mentioned earlier that the number of cows carried per 1,000 acres of sown grass in the main dairying areas had increased by 128 per cent in the period 1920-40. Impressive as this improvement is, it has little more than scratched the surface. Madden's survey of North Island pastures (*see* N.Z. Dept. of Sci. Ind. Res. Bull. 79, 1940) and Hilgendorf's (*see* N.Z. Dept. of Sci. Ind. Res. Bull. 47, 1935) of the South Island have made abundantly clear

the scope for further improvement. These surveys have provided a most useful stocktaking, but they do emphasize the lag between demonstration and application in practice. The best of our pastures in the North Island (Madden's type 1) cover an area of only 100,000 acres, or 0·65 per cent of the total sown grassland. Conceding a more liberal interpretation of a good sward to embrace types 1 to 3 raises the area to 2,041,000 acres, or 13·9 per cent out of a total of 14,718,000 acres in grass.

It would be costly rapidly to convert the ploughable areas in the lower-producing types into high-producing categories, but the present rate of conversion might profitably be accelerated. It has been amply demonstrated on the gum lands of the North and on the light soils around Rotorua that high-producing pasture can be profitably established and maintained on these soil types by choice of suitable seeds mixtures, by top-dressing, and by exercise of good management practices. There is a tremendous reservoir of potential production in our pastures as yet scarcely tapped.

Top-dressing

The use of phosphates and lime as top-dressing for sown grassland expanded very rapidly after 1920. Data were not collected until 1936, when 1,521,000 acres were top-dressed. By 1930 the area treated had expanded by 89 per cent to 2,871,000 acres (*see* Fig. 1), but during the depression years the area decreased and it was not till 1935 that the 1930 level was regained. In 1940, 4,649,000 acres were top-dressed with either lime or artificials, that is, slightly more than three times the area covered in 1926.

Response to phosphates is general in the areas devoted to dairying, and a great deal of detailed research has been devoted to determining optimum rates and times of application. The work of Hudson and his co-workers at Marton and Ruakura (*see* N.Z. Dept. of Sci. Ind. Res. Bull. 31, 1933) has established that small frequent applications of phosphate give greater total production and better seasonal spread than the same quantities applied at less frequent intervals. Contrary to opinions sometimes expressed (Connell, 1938), a phosphatic top-dressing lessens the difference in the rate of production between spring and winter (*see* N.Z. Dept. of Sci. Ind. Res. Bull. 31, 1933), but because of the greater number of stock carried it does increase the need for conservation of hay and silage if adequate provision is to be made for winter feed.

Fawcett has published a number of analyses (*see* N.Z. Dept. Agric. Bull. 138, 1929) showing the relationship between rate of top-dressing and level of production on dairy-farms, and his figures make clear the close association between adequate top-dressing, high carrying-capacity, and high production per acre. There has been a tendency, however, to assume that if 2 cwt. per acre were good, 4 cwt. must be better. There is little doubt that phosphates have been applied lavishly and in many cases wastefully. The total quantity of minerals sold off the farm is not large. Assuming a production of 150 lb. of fat per acre (average 4·5 per cent test), the amount removed in the milk per annum is equivalent to only 41 lb. superphosphate, 26 lb. of 30 per cent

potash salts, and 10 lb. of ground limestone. A major portion of these minerals on farms where home separation is carried out remains in the skim-milk and is largely deposited on pig paddocks. There is a considerable waster of manurial value in drainage from milking-sheds and pigsties, however, which might be conserved and returned to pastures. Some minerals are also retained by the growing animal, but the quantity is small compared with that required for lactation.

What has not always been clearly understood is that top-dressing with lime and phosphates is mainly an indirect method of supplying nitrogen to the sward through the medium of clovers. Without legumes in the sward, response to top-dressing is often poor or lacking, and benefit of the vigorous pedigree types of white clover developed by the Grasslands Division is likely to be reflected in improved utilization of applied phosphate. The animal also plays an essential role in the complex cycle inaugurated by top-dressing. Recent work (Sears and Newbold, 1942) on the influence of the grazing animal on the pasture has provided an interesting measure of the all-important part played by the return of animal droppings during the grazing process. Using wethers as the grazing animal and collecting dung and urine in containers suspended from the animals grazing certain plots, a measure was obtained of the effect of these on production. The results are outstanding in emphasizing the magnitude of the return of fertilizing ingredients in the dung and urine of the mature grazing animal on a high-producing pasture. In the first season the dung and urine returned in normal grazing contained the equivalent of 15 cwt. sulphate of ammonia, 6 cwt. superphosphate, 8·75 cwt. of 30 per cent potash salts, and 2·25 cwt. of ground lime. Four cwt. of superphosphate was applied to the plots at time of sowing, and it is clear from Sears's figures that in the first year more than this amount was returned to the pasture via the animal. There is a large field of work here about which we have little accurate information, and an extension of the work as opportunity permits seems likely to yield results of far-reaching importance. Is it possible that, having once initiated good clover growth of a vigorous type, production may be sustained with quite small dressings of phosphate ?

On some soils, applied phosphate is " fixed " in a form unavailable to plants (Birrell, 1938). Fixation can be minimized by applications of lime prior to phosphating or by using a " reverted " phosphate, and considerable interest has recently centred round the use of serpentine-superphosphate. Wide-scale tests have shown that in a majority of cases serpentine-super gives a response equal to the same amount of " straight " super (Elliott and Lynch, 1941), with a saving of one-third in the amount of phosphate applied. Considerable research is proceeding overseas in an effort to improve the efficiency with which phosphate is used in the soil (*see* U.S. Nat. Res. Comm., 1937, Nordengren and Lehrecke, 1940), and a close watch should be kept on developments.

Lime as well as phosphate is deficient in many New Zealand soils. The practice of liming pastures has been growing in recent years and, with the exception of Taranaki, lime-crushing plants are well distributed throughout

the dairying areas. The response to lime is greatest in Southland, North Auckland, and the northern parts of the Auckland Land District. In 1940-41, some 1,826,000 acres were top-dressed with either lime alone or with lime and fertilizers. Prices average from 11s. to 15s. per ton ex works, and free railage up to one hundred miles is provided in order to encourage the use of lime. In 1940-41 the average dressing with lime was only 4 cwt. per acre, which is scarcely sufficient to replace annual losses by leaching. Very much heavier dressings are essential if marked benefit is to accrue.

Fertilizers other than phosphate and lime have in the past been little used on grassland, though limited areas in Taranaki have been regarded as potash deficient. It appears reasonable to suppose, however, that, as the phosphate and lime status of our dairying soils improves under continued top-dressing, other nutrients such as potash and magnesia are likely to become limiting factors to production.

Pasture Utilization

The benefits to be expected from the adoption of improved pasture strains and top-dressing may be completely nullified unless coupled with adequate utilization at the correct stage of growth. With growth rate dependent in large degree on the vagaries of climate, complete utilization at the correct stage of growth remains an elusive ideal. Nevertheless, considerable progress has been made in the development of a grassland technique in recent years, and New Zealand farmers are pasture-conscious to an unusual degree. Rotational grazing, in some measure, is widely practised, but on too many farms gates are left open and fences are in poor repair.

Heavy surface cultivation of grassland was advocated at one time, and special types of harrows were developed for this purpose. Experiments have failed to show any benefit from such treatment on well-managed swards (Woodcock, 1938), and harrowing now tends to be confined to the spreading of droppings. Topping of pastures to prevent seeding during early summer is also practised on intensively farmed areas. It could with advantage be more widely practised, but with normal horse-drawn equipment is too time-consuming. If tractor mowers taking a wider swathe were available at a reasonable price, one would expect the practice to expand. Statistics are lacking in regard to the essentially grassland implements used in farming.

More intensive stocking of grasslands with more complete utilization of the feed produced has rendered the grassland farm more sensitive to seasonal or climatic changes in growth rate. When it became no longer the practice to maintain a certain amount of roughage on pastures as a reserve of feed, there was increasing need for the conservation of surplus spring production to tide over critical periods of low production. The area of hay and silage harvested (shown in Fig. 1) increased very rapidly from 1920 to 1933, but apart from seasonal fluctuations has since remained relatively constant.

The methods of conservation of fodder as hay or silage have undergone little change, apart from the introduction of labour-saving machinery. In a survey of silage stacks in the 1940-41 season (Coop, Sears, Thurston and Sill,

1941), wastage was estimated to average 25 per cent and much of the material was of inferior quality. In addition to this direct and obvious loss, there is also a loss of dry matter due to bacterial action amounting to approximately 30 per cent, so that total losses may easily be of the order of 50 per cent. Losses in haymaking due to weathering, heating in stack, poor thatching, etc., may easily be of the same order. A continuation of present research in order to find ways of limiting these losses is very desirable. It is possible that A.I.V. silage or even grass-drying may not seem so uneconomic when we have a clearer picture of losses under our present methods.

The scope for increased conservation of hay and silage is very great. Connell (1938) has pointed out that in an " average " season over 50 per cent of pasture production occurs in the period October-December, while only 30 per cent of the feed requirements of a dairy herd fall in the same period, that is, 40 per cent of grass production in this period is surplus to herd requirements in a normal season. In actual practice, approximately 17 per cent of the area used for dairying was saved for hay or silage in South Auckland in 1939-40 and 16 per cent in Taranaki, but only 7 per cent in North Auckland. While conservation of the whole of that 40 per cent surplus may not be possible, there is obvious scope for much improvement in North Auckland and for a further increase in other areas.

The tendency in recent years has been for earlier calving of cows with increase in the average length of lactation. Cows may be calved down when little feed is available in the spring and will draw on body reserves to maintain lactation until the spring flush of pasture growth commences. Experiments have been made in the use of nitrogenous dressings to produce out-of-season grass (*see* N.Z. Dept. of Sci. Ind. Res. Bull. 31, 1933), but the method has never been widely applied. Marryat, however, drew attention to the " cool storing " of late-autumn growth (Marryat, 1937) for use in the early spring, and Riddet (1938) has suggested a refinement which provides a useful means of providing feed to tide over this period.

In spite of our natural advantages, complete reliance on pasture growth would hardly have been possible had it not been that the efficiency of modern refrigeration, by smoothing supplies to the market, allowed seasonal production to be adopted. The seasonal curve of dairy production follows very closely the curve of pasture-production, but it is probable that too low a plane of nutrition is a limiting factor to production in over 50 per cent of our herds. Dry spells in January-February frequently decrease production, and many cows are inadequately fed during the winter months. Districts such as Taranaki with a high average production per cow are notable for the way in which they maintain production in the autumn and for the longer lactation they achieve.

Various methods of overcoming weaknesses in our present complete dependence on pasture such as top-dressing, conservation of hay and silage, use of improved strains with better seasonal spread, and the use of autumn grass " cool-stored " through the winter have already been widely adopted, though there is great scope for further extension in these directions. May it

be, however, that in our efforts to reduce demands on labour and capital we have become too dependent on grass? Even from a grassland point of view, would it not be profitable to plough our permanent swards at long intervals, take one or perhaps two supplementary crops to provide succulent feed for winter or autumn feed, and resow with improved strains of grasses and clovers? Lack of necessary equipment is a limiting factor to any such development at the moment, but if a suitable small-type tractor of low first cost were available this difficulty might be overcome.

New Zealand lies in the track of prevailing westerly winds often accompanied by cold showers, and the provision of shelter-belts and hedges to provide protection for both stock and pastures is widespread. Many farms, however, are inadequately sheltered (Yeates, 1942), and stream-banks and rough unploughable areas on many farms could with advantage be planted with trees to provide both shelter and timber.

Production per Acre

Production from grassland is not so readily measured as in the case of annually harvested crops. Stock-carrying capacity is a ready measure of pasture production. The marked increase in carrying capacity in the main dairying areas in the past 20 years has already been discussed, but there is little published information in respect of actual pasture production.

Hudson (1933), in a series of mowing and grazing trials at Marton, obtained dry-matter yields of 4,638 lb. to 8,506 lb. per acre. Marton, however, is not a dairying district, and unfortunately very few farmers could hope to maintain the sward in the condition in which it is kept in these trials; the technique is therefore somewhat unsatisfactory as a means of studying pasture-production under farm management (Elliott and Lynch, 1942). Elliott and Lynch (1942) have developed the "enclosure method," which involves "the least change from standard farm management, and has proved very satisfactory both with sheep and dairy-cattle grazing." Yields obtained by this method at Karamu, in the Waikato, were 9,037 lb. of dry matter in the 1939-40 season and 11,787 lb. in 1940-41. Similar trials in other districts in the 1940-41 season gave dry-matter yields of 4,734 lb. at Stratford, 11,071 lb. at Marton, and 6,269 lb. at Winton. A small-scale trial at the Grasslands Division in 1940-41 gave yields of 13,675 lb. dry matter (Sears and Newbold, 1942) under a system of intensive rotational grazing with sheep. These data are very sketchy when one considers the reliance placed on grassland production in the Dominion. They do, however, indicate the very high level of production which may be attained under good management and full utilization. This becomes more apparent when it is considered that a dairy cow producing 1 lb. of butterfat per day requires approximately 7,300 lb. of dry matter per year (Elliott and Lynch, 1942).

A more generally accepted standard of efficiency has been production of butterfat per acre, but here again little specific information is available for the industry as a whole and most of the data relate to individual farms and

not to districts. Production of butterfat per acre is determined by the equation—

$$\frac{\text{Cows milked} \times \text{average butterfat per cow.}}{\text{Area of farm.}}$$

As farm area is not readily adjustable, improvement in per-acre production must be accomplished by increasing carrying capacity or improving butterfat-production per cow. Both these lines of attack have been pursued vigorously over the past 20 years and, as has already been shown, considerable advances have been made. There is no measure, however, of changes in the area devoted to dairying, so that trends in production per acre cannot be accurately defined, though the increase must have been very considerable.

Fawcett (1932), in an analysis of data from 967 farms in the main dairying areas in 1929-30, found an average per-acre production of 112 lb. He comments, however, that " if an average could be taken over all farms in New Zealand a much lower scale of production would be presented." The Government Statistician, in a survey of 19,307 farms in the 1935-36 season (*see* N.Z. Official Yearbook, 1938), found an average production of 105 lb. per acre, and owing to the size of the sample taken this was probably very close to the Dominion average at that time. The survey conducted by the Department of Agriculture for the Dairy Industry Commission (1934) also provides information for a highly selected sample of 550 farms on a district basis. The figures for the main dairying areas in the 1933-34 season were : North Auckland, 93 lb. per acre ; Auckland, 144 lb. ; Taranaki, 122 lb. ; and Manawatu, 134 lb. per acre.

The fact that under favourable conditions and expert management figures as high as 350 lb. of butterfat per acre can be attained gives some measure of the scope for improvement in the industry as a whole. Such figures can scarcely be expected as possible averages, but a figure approaching 200 lb. per acre should be within reach in our intensive dairying areas.

Soil Surveys

As farming extended into the central volcanic plateau it was found that, though pastures established satisfactorily, stock did not thrive. Cattle and sheep particularly developed an anæmic condition known as bush sickness, which could be cured only by shifting them to other areas. Stock mortality was high, and while attempts were made to find a solution of the problem, many farms were abandoned and development halted. A partially satisfactory solution was obtained by feeding stock with citrate of iron and limonite supplements. In an effort to delimit the affected areas, two geologists were detailed to map the ash showers in the area and were successful in showing that bush sickness was confined to soils derived from two only of the five main ash showers covering the area (Grange, 1931). This survey was the genesis of the Soil Survey Division of the Department of Scientific and Industrial Research in New Zealand.

Obscure stock ailments in other areas such as Morton Mains in Southland and Glenhope in Nelson were shown to be cured by the administration of

cobalt, and bush sickness in the North Island has been shown to be merely a severer form of the same deficiency. Satisfactory methods have now been devised for the application of cobalt to affected areas as cobaltized-superphosphate, and this practical solution of the problem has made possible the use of considerable areas for dairy settlement in the central volcanic plateau in the North Island. There are other border-line areas where incipient deficiencies of cobalt occur in some seasons, and our knowledge of these areas could profitably be systematized on the basis of the soil map of the North Island now available.

While the original survey of the pumice areas was hardly a soil survey in the now commonly accepted sense of the term, it helped to gain support for the setting-up of an organization which was suited to carry out a general stocktaking of our soil resources. Detailed surveys of the various areas have been made by the Soil Survey Division (*see* N.Z. Dept. of Sci. Ind. Res. Bull. 65, 70, 71, 72, 76, 1939, and Hamilton and Grange, 1938) and by the Cawthron Institute in Nelson.

Since the outbreak of war a general reconnaissance survey of the North Island has been brought to completion and a considerable portion of the South Island has also been mapped. These reconnaissance surveys are fundamental to any attempt to plan land use, in dealing with problems of land deterioration and soil erosion, or in planning extensions of land-development for rehabilitation or other purposes.

It may be as well at this point to digress for a moment and consider the objects of soil surveying. " The soil map is designed to show the location and extent of the various kinds of soil in an area with sufficient detail . . . to indicate these differences significant to man in using the land for the growth of plants " (*see* U.S. Dept. Agric. Misc. Publ. 274, 1937). Surveys perform an important function in providing an inventory of soil resources, but their most important use should be as a basis for " classifying the results of experience and experiments regarding the characteristics and use capabilities of soils." The maps in themselves are of value mainly in so far as they are intelligently used as a basis for systematizing other knowledge. Using as a basis the soil maps and the results of field experiments carried out by the Department of Agriculture, supplemented by laboratory and field observations, it should now be possible to draw up " single factor " maps showing response to liming, fertilizers, etc. These might divide the type of response into, say, five categories or grades and present a simpler and more readily interpreted pattern than the soil map and one more intelligible to the practical farmer. Projects of this type are now under way, and a lime-response map of the North Island has been completed on a scale of 4 miles to the inch.

In Canada and the U.S.A., soil maps have also been used as a basis for land classification. This may involve little more than a grouping of the soil types according to their natural characteristics or according to their productivity for specific crops such as wheat ; it may involve grouping of soil units on the basis of recommended use or it may involve such complete detail as that required for placing a rating on individual farm units for purposes of

valuation. A crop map for the Heretaunga Plains area (Hastings) has already been published (*see* N.Z. Dept. of Sci. Ind. Res., Bull. 70. 1939).

Soil as the medium for plant growth is the basis on which our whole pastoral industries depend, and we cannot have too much information about its characteristics and the distribution of different types. Fertilizers and lime represent rather more than one-third of the main working-costs in producing butterfat (*see* N.Z. Official Yearbook, 1938). Soil surveys in conjunction with field trials should permit the more economical use of fertilizers by delimiting those areas showing response and giving a better understanding of fertilizer requirements for most economic production. By a national stocktaking of our soil resources they can also indicate where farm development might be undertaken with reasonable prospects of success as well as delimit eroded areas where immediate steps must be taken to alter farming methods to prevent further deterioration or else withdraw land from farm use altogether and reclothe it in protective forest.

Scope for Expansion

Provided that the demand for dairy products exists at reasonably profitable prices, the avenues of possible expansion may be broadly grouped under three heads :

(*a*) by more intensive farming of areas at present used for dairying ;

(*b*) by diversion of land at present used for fat-lamb raising or fattening of beef cattle to dairying ;

(*c*) by development of land at present lying idle but capable of being utilized for dairying.

The possibilities of more intensive use of existing dairying land have been vigorously exploited during the past 20 years, but the limit of expansion has by no means been reached. The number of dairy cows carried per 1,000 acres of sown grass in the main dairying areas increased by 68 cows in the 1920-30, and by 66 cows (38 per cent) in the period 1930-40. There is thus no evidence that the rate of improvement in carrying capacity is slowing down, though there obviously must be an upper limit, as yet undetermined. Progress in per cow production (all cows in milk) was rapid over the period 1920-30, approximately 50 lb. per cow, but has slowed up markedly in 1930-40, approximately 14 lb. per cow. There is no reason why the 1920-30 rate of improvement should not be resumed after the war, if techniques of animal improvement already in use overseas are adopted locally, and full use is made of existing knowledge of pasture improvement and management. If these possibilities were to be realized, it is estimated that an increase of 50 per cent in production from the existing land used for dairying should be possible in a comparatively short period.

Much of the land used for fat-lamb raising is in lower rainfall areas, or where summer and autumn rainfall tends to be uncertain. Much of this area is divided into large blocks unsuitable for dairying. Changes are likely to be slow unless relative prices of dairy products and lambs change, or the effect of competition with artificial fibres begins to be felt.

The scope for expansion of dairying on land at present lying idle appears to be quite considerable. For example, on land north of Auckland there are approximately 934,000 acres suitable as regards soil and topography for dairying or fat-lamb raising. At an average of 2·25 acres per cow, this would suffice to carry 415,000 cows as against 265,000 already in the area, a potential increase of 56 per cent if none of the area were to be used for other purposes.

In discussing the relations between British agriculture and imports from New Zealand, Hamilton states that " there is an unfortunate impression current among certain sections of the British farming community that all competing imports are the products of exhaustive agriculture or that their overseas competitors are blest with superior advantages of soil or climate or cheap labour. The British farmer has had, and is always likely to retain, a preferential price margin for his home-grown produce more than sufficient to compensate for any shortcomings of soil or climate. Whether he can secure additional subsidies from the urban section of the community is doubtful, since in the long-run such subsidies must be added to the cost of exports through higher wages necessary to sustain a reasonable standard of living. Such a policy is likely to be faced with strong opposition from the export industries.

" Quite apart from these considerations, there appears to be ample scope for maintaining the production of necessary ' protective ' foods of a perishable character, for example, fresh milk, eggs, etc., at a much higher level than pre-war, and this, together with a semi-luxury demand for home-grown produce and the placing of less reliance on imported animal-feeding stuffs, should suffice to absorb the productive energies of British agriculture. Its permanency as a long-term policy on other lines than these seems doubtful, and the United Kingdom will find it necessary to consider from many angles the implications of a policy of self-sufficiency for her agriculture. There seems little reason to believe that it is likely to be a serious menace to New Zealand primary industries."

Land Deterioration

In recent years attention has everywhere been focused on problems of land deterioration and more particularly on the more spectacular phases of soil erosion as they have developed in certain overseas countries. The problem has been reported upon in New Zealand (*see* N.Z. Dept. of Sci. Ind. Res. Bull. 77, 1939), and while it rarely exhibits the spectacular features of erosion seen in the " dust-bowl " and elsewhere, it is perhaps all the more dangerous because less apparent and therefore more likely to be ignored.

Taylor has reported (*see* N.Z. Dept. of Sci. Ind. Res. Bull. 62, 1938), that " over most of the hill country the fertility is falling and the produce—sheep, wool, and cattle—has been lavishly subsidized by the land itself." Dairying, however, is concerned more particularly with the gently-rolling and flat lowlands, and on those the original forest covering has been replaced by a close pasture turf. "The fertility of the land is rising and the produce—milk, butter, cheese, fat lambs, and the like—has been fairly won."

From other aspects, however, the dairy-farmer cannot remain indifferent to the threat of continued deterioration of the hill country. Many dairying areas in the Manawatu, and smaller areas such as occur in North Auckland, are subject to flooding, the frequency and extent of which tends to increase as the hill country is denuded of its forest. Over a much wider area, too, farms rely on water from streams or springs, and these sources tend to fluctuate more widely and may fail altogether in summer because water-sheds have been deforested.

In many districts, including parts of Taranaki and Waikato and much of North Auckland, dairying land is intersected by deeply-entrenched streams or contains broken faces unsuited for pastures. In clearing the land these areas were in some cases wisely left in forest, but all too often they were cleared and, failing to hold a sward, have become a harbour for noxious weeds. Such areas might profitably be planted in timber-trees to supply firewood and fencing-material for farm use or sale. We have been too prone to regard forestry as something only suited to large-scale operations and entirely divorced from farming, but during the depression many farmers welcomed the ready money that they received for odd pines of millable size. The practice of planting waste areas with timber-trees would benefit the farm by providing shelter, and in a few years would come to represent a valuable asset against hard times. Forestry is regarded as a normal part of farm activity in most European countries, and the woodlot helps to even out labour demand by providing work during the winter months. Around Stockholm, for instance, 80 per cent of the land is under forest, forest which forms an integral part of the farm unit, and, in total, contributes largely to the Swedish production of forest products. Our climate in this country is admirably suited to the growth of softwoods, most dairying areas are fairly intensively settled and modern methods of transport have overcome major obstacles to utilization of small stands of timber. There is tremendous scope for replanting of small areas in most dairy areas, an activity which would help to control weeds, conserve water-supplies, provide a useful investment, and considerably improve the amenity value and productivity of the countryside.

References

Birrell, K. S. 1938. Phosphate fixation in some New Zealand and Pacific Island soils. *N.Z. J. Sci. Tech.* Vol. 19. pp. 652-6.

Connell, R. P. 1938. Some features of current land utilization. Pap. 7th Ann. Conf. N.Z. Grassland Assoc. pp. 1-14. [Discussion pp. 1-3.]

Coop, I. E., Sears, P.D., Thurston, W. G., and Sill, F. B. 1941. The quality of stack silage in the 1939-40 season. *N.Z. J. Sci. Tech.* Vol. 23. pp. 121A-5A.

Elliott, A.G., and Lynch, P. B. 1941. Serpentine-superphosphate. *N.Z. J. Agric.* Vol. 63. pp. 177-85.

———————— 1942. Grassland production in New Zealand. *N.Z. J. Agric.* Vol. 64. pp. 103-13.

Fawcett, E. J. 1932. Butterfat production in New Zealand: factors influencing unit-area production, with special reference to milk-test. *N.Z. J. Agric.* Vol. 44. pp. 235-52.

Grange, L. I. 1931. Volcanic ash showers. *N.Z. J. Sci. Tech.* Vol. 12. pp. 228-40.

Hamilton, W. M., and Grange, L. I. 1938. The soils and agriculture of Western Samoa. *N.Z. J. Sci. Tech.* Vol. 19. pp. 593-624.

HUDSON, A. W. and others. 1933. See New Zealand, Dept. Sci. Ind. Res. Bull. 31.
LEVY, E. B. 1932. New Zealand pasture seeds: what the Dominion has to offer. *N.Z. J. Agric.* Vol. 44. pp. 309-15.
———— and GORMAN, L. W. 1934. Strain investigation in white clover. *N.Z. J. Agric.* Vol. 49. pp. 86-104.
MARRYAT, E. R. 1937. Winter grass. *N.Z. J. Agric.* Vol. 55. pp. 155-7.
NEW ZEALAND, Department of Agriculture. 1929. Bull. 138. Dairy-farm management. A survey of farms in the Waikato and Taranaki districts, season 1926-27. By *E. J. Fawcett.* pp. 68.
NEW ZEALAND, Department of Scientific and Industrial Research. 1933. Bull. No. 31. Investigations into pasture production. By *A. W. Hudson, B. W. Doak* and *G. K. McPherson.* pp. 197.
———— 1935. Bull. No. 47. Grasslands of the South Island of New Zealand. By *F. W. Hilgendorf.* pp. 24.
———— 1938. Bull. No. 62. Land deterioration in the heavier-rainfall districts of New Zealand, By *N. H. Taylor.* pp. 657-81.
———— 1939. Bull. No. 65. Soil survey of Duvauchelle Bay—Wainiu District, Banks Peninsula. By *C. S. Harris* and *A. C. Harris.* pp. 13.
———— 1939. Bull. No. 70. Land utilization report of the Heretaunga Plains. pp. 111.
———— 1939. Bull. No. 71. Soil survey of Westport District. By *C. S. Harris* and *A. C. Harris.* p. 23.
———— 1939. Bull. No. 72. Soil survey of Wairau Plains. Marlborough. By *C. S. Harris and K. S. Birrell.* pp. 29.
———— 1939. Bull. No. 76. Soils and agriculture of part of Waipa County. pp. 85.
———— 1939. Bull. No. 77. Maintenance of vegetative cover in New Zealand, with special reference to land erosion. pp. 51.
———— 1940. Bull. No. 79. Grasslands of the North Island of New Zealand. By *E. A. Madden.* pp. 45.
NEW ZEALAND, Official Yearbook. 1938. Dairy-farm survey. N.Z. Off. Yearb. Wellington, 1938. pp. 429-48.
NORDENGREN, S., and LEHRECKE, H. 1940. Possible development of the superphosphate industry. *Chemical Age.* Vol. 42. pp. 139-42.
Report of the Dairy Industry Commission. Govt. Printer, Wellington. 1934.
RIDDET, W. 1938. The relation of pasture species to quantity and quality of milk. Pap. 7th Ann. Conf. N.Z. Grassland Assoc. pp. 1-12.
SEARS, P. D., and NEWBOLD, R. P. 1942. The effect of sheep droppings on yield, botanical composition, and chemical composition of pasture. *N.Z. J. Sci. Tech.* Vol. 24. pp. 36A-61A.
UNITED STATES, Department of Agriculture. 1937. Misc. Publ. 274. Soil survey manual. By *C. E. Kellogg.* pp. 136.
————, National Resources Committee. 1937. Technological trends and national policy. Washington, 1937.
WOODCOCK, J. W. 1938. Harrowing of pastures. Pap. 7th Ann. Conf. N.Z. Grassland Assoc. pp. 1-5. [Discussion p. 1.]
YEATES, J. S. 1942. Farm trees and hedges. Massey Agric. Coll. Bull. 12. pp. 208.

TRIALS OF HERBAGE PLANTS AT LINCOLN, NEW ZEALAND

As there are in New Zealand a number of districts that are quite distinct ecologically, it has been considered desirable to open a substation of the research station at Palmerston North on land belonging to the Agronomy Division at Lincoln, Canterbury, South Island. Since its establishment in 1938, introduced and local strains of all the pasture species of importance in New Zealand have been tested and pedigree selections are being compared with commercial lines.

Climatic conditions at Lincoln are markedly different from those at Palmerston North, the greater extremes of temperature and rainfall being less favourable to pasture growth. The conditions at Lincoln are as typical of those in most parts of the South Island as those at Palmerston North are typical of the North Island. The following are some extracts from the report of observations at Lincoln published by L. W. Gorman and J. P. Lambert in the *New Zealand Journal of Science and Technology* 25. No. 2, pp. 73-80, 1943.

Lolium perenne. In plot trials, N.Z. pedigree and certified lines have proved best, with only the Aberystwyth " hay " and " dual-purpose " types approaching them in production and persistency. Other strains noted as generally inferior are N.Z. uncertified, " Svalöf Victoria," Irish, Scottish, and the Australian varieties, " Colac," " Clunes," and " Western Districts."

Trials of tiller rows have given results similar to those at Palmerston North (Levy and Davies, *N.Z. J. Agric.* 41. 147-63. 1930). In single plant studies, the behaviour of pedigree, mother seed, and uncertified lines has been similar at Lincoln and Palmerston North. Eighty per cent of the single plants of the Aberystwyth " pasture " type died out within the first two years, being unable to stand the dry summer of 1940-41 ; the Aberystwyth " hay " type showed only 18 per cent mortality.

Lolium multiflorum. Two trials were sown in March, 1939 ; in Trial 1 the strains were sown pure, while in Trial 2 there were replications of pure sowings of Italian ryegrass strains (*a*) alone, (*b*) plus N.Z. Broad Red clover (*Trifolium pratense*), and (*c*) plus Govt. stock Montgomery Red clover. The results are given in Tables 1 and 2, while percentage survival is given in Table 3.

TABLE I.—RELATIVE YIELDS OF ITALIAN RYEGRASS STRAINS (Trial 1).

(Trial sown, 28/3/39 ; completed, 23/10/40. Mother seed Italian=100.)

Strain.	Up to 4/9/39	4/9/39 to 4/12/39	5/12/39 to 1/3/40	1/3/40 to 21/5/40	21/5/40 to 19/8/40	19/8/40 to 23/10/40	Totals
Nucleus pedigree ...	100	104	116	126	110	102	106
Mother seed	100	100	100	100	100	100	100
Uncertified	89	98	100	74	80	89	92
Western Wolths ...	111	88	25	...	...	...	55

TABLE 2.—ITALIAN RYEGRASS STRAINS WITH AND WITHOUT RED CLOVER.

Yields, in tons per acre, of green herbage from 25th March, 1939, to 13th December, 1940 (Trial 2).

	Pedigree			Mother Seed.		
	Italian ryegrass	Red Clover	Total	Italian ryegrass	Red Clover	Total
Italian ryegrass only	10.65	...	10.65	9.45	...	9.45
Italian ryegrass + Broad Red clover	10.47	4.83	15.3	9.49	4.85	14.34
Italian ryegrass + Montgomery Red clover	11.0	6.19	17.19	10.81	6.27	17.08

TABLE 3.—PERCENTAGE SURVIVAL OF ITALIAN RYEGRASS STRAINS 14 MONTHS AFTER PLANTING.

Strain	Percentage survival
Pedigree	66
Certified mother seed	47
Uncertified	14
Western Wolths	Nil

Short-rotation ryegrass. "Work has been proceeding for some time on the production of a new type of ryegrass which is best described as 'short rotation.' This type is designed to satisfy the needs of those farmers whose land will not hold permanent pasture longer than 3 to 5 years, and also those who normally do not want a truly permanent pasture but for whom Italian ryegrass is too short-lived. The desired type is one which will persist for about four years and produce more than perennial ryegrass in that period.

"At Lincoln, 184 tiller rows have been planted, duplicating a series in Palmerston North. They are made up from plants selected from single plant trials and embrace naturally occurring types approaching the type aimed at, artificial hybrids, persistent Italian ryegrass plants, and typical perennial ryegrass plants. These were planted at Lincoln in spring, 1939, and have provided useful comparisons with the Palmerston North series.

"Experimental increase blocks have been grown in Palmerston North, and seed harvested from these is incorporated in a production trial at Lincoln comprising two short-rotation strains, certified mother-seed Italian ryegrass, 1939 and 1940 pedigree Italian, and certified mother seed perennial ryegrass.

"The one short-rotation strain (Cg. 1) has shown high productivity combined with good recoveries for the period that the trial has been in progress (15 months). For the first 9 months its yield of 4.4 tons of green matter per acre was equal to that of the Italian ryegrass selections. Since then the Italian selections have made little recovery, but the short rotation is still growing well. In the first 15 months it has produced practically twice as much herbage

as the mother-seed perennial ryegrass, the yields of green matter per acre being 5.42 tons and 2.83 tons respectively.

" Single plants of the short-rotation strains confirm the above recorded results from plot sowings ; as single plants they are vastly superior to plants of uncertified ryegrasses such as are being used in short-rotation pastures at the present time."

Dactylis glomerata. Observations have been made on growth and degree of winter burning. Danish and Swedish lines have a long period of winter dormancy and considerable winter burning. The Aberystwyth "pasture" type is most free from winter burning, being superior to " C23 " and the Aberystwyth " dual purpose " type ; the Aberystwyth " hay " type and the Akaroa type are slightly worse in this respect.

Phleum pratense. Aberystwyth S51 (hay type) and American Commercial are best for summer growth, followed by S48, Swedish, and S50. The herbage dries off in the summer, and early winter growth is most marked in S50 (pasture type). In early spring the Welsh " hay " and " dual " types have made the best growth, followed by the pasture type.

Poa pratensis. Wide strain differences exist in this species. Four varieties have been tested, ordinary commercial, and the Swedish " Primo," " Skandia " and " Fylking." " Primo " is a broad-leaved type, superior at most seasons for growth, and most free from winter burn.

Miscellaneous species. Introduced and indigenous grasses are being studied in the hope of finding species suitable for drier and colder habitats. These include introduced species of *Agropyron* and *Bromus*, also the indigenous *Agropyron scabrum* and *Dichelachne crinita.*

Trifolium repens. Results confirm those obtained at Palmerston North (Levy and Gorman, *see Herb. Abstr.* 3. p. 198. 1933). Welsh pedigree is equal to N.Z. pedigree in late spring, slightly superior in early autumn, but inferior in late autumn. During winter it has fallen to 70 per cent of the yield of N.Z. pedigree.

Trifolium pratense. Differences have been similar to those obtained at Palmerston North (Levy and Davies, *see Herb. Abstr.* 1, p. 24. 1931). Certified Essex Late has compared favourably with N.Z. Broad Red, and Aberystwyth pedigree Montgomery with N.Z. pedigree Montgomery.

Trifolium subterraneum. Strain differences are similar to those already noted (Levy and Gorman, *N.Z. J. Agric.* 54. 82-94. 1937). " Mulwala " is the most leafy of the early strains, " Bacchus Marsh" has compared favourably with " Mount Barker " in the early part of the season, but is seriously affected by rust in early spring. " Tallarook " is the most productive late strain, is a very good reseeding type, being able to grow and re-establish itself very successfully.—R. O. WHYTE.

THE HERBAGE SEED POSITION IN THE UNITED STATES OF AMERICA

During the last war, when the United States was called upon to produce more food, the government became aware of the necessity of some organization to be responsible for the production, storage, and distribution of seed, the precursor of food. In 1917, the Secretary of Agriculture created a Committee on Seed Stocks the function of which was to make a seed survey and look into the supply of and demand for seed. The Committee worked in co-operation with the Grain Corporation, the seed associations, the Food Administration and the War Trade Board, and, as a result of their deliberations, the Department of Agriculture obtained, for the first time in its history, a close-up view of the country's seed supply. In the war of 1914-1918 the great demand was for wheat and maize ; now it is for vegetables, oil plants, beef and dairy products. The change, which reflects a change in diet, creates a demand for a plentiful supply of grass and legume seed. It is to deal with this new situation that the Departmental Seed Production Programs Committee has been formed.

"The War Food Administration has long felt the need of a central source of data on the various questions on grass and legume seed—a means of marshalling every bit of pertinent information existing in the Department [of Agriculture]. Accordingly, J. B. Hutson, director of the Food Production Administration, has appointed a committee of representatives from the several interested branches in the Department to formulate recommendations dealing with seed programs.

"In appointing the Committee on Seed Programs Mr. Hudson stated : ' The providing of adequate supplies of grass and legume seeds is one of the most difficult and important food production problems. This is especially true in connection with the maintenance of a high level of production over a period of years.' " (Brown, 1944a).

The chairman of the committee is C. R. Enlow of the Soil Conservation Service. Committee members represent the Production Programs Branch, Food Distribution Administration, Bureau of Agricultural Economics, Extension Service, Bureau of Plant Industry, Soils and Agricultural Engineering, Soil Conservation Service, Agricultural Adjustment Agency, Commodity Credit Corporation, and the Food Distribution Administration. The committee is stressing the importance of high quality seed as evidenced by its proposal for the war emergency production of improved grass and legume seeds, and by its recommendations on price support for State certified seed of varieties and strains of alfalfa, red clover, sweet clover and timothy. It has also made detailed recommendations regarding the export, import and distribution of present seed stocks.

The Soil Conservation Service is taking a leading part in the production of grass and legume seed. For the past 8 years or more, it has been testing new strains, multiplying seed of promising varieties in its nurseries, and distributing the seed to farmers through the soil conservation districts. In the South-east alone 73 tons of seed of promising new crops for soil conservation

purposes have been produced. It is expected that, in time, these seeds will be available through the seed trade; the Soil Conservation Service will then curtail production.

The outlook for the country as a whole, as regards herbage seed, is not bright. Production in 1943 was below that in 1942 which, in turn, was lower than that of 1941. In some quarters, the next 2 years are considered to be critical. Table 1 summarizes the present position for the principal forage crops. The data were obtained from the Division of Agricultural Statistics, Bureau of Agricultural Economics; they represent the best information at December 1942 and December 1943. The discrepancy in price between these two dates is an indication of the seriousness of the seed situation.

TABLE 1.—CLEAN SEED PRODUCTION, CARRY-OVER, AND PRICE TO GROWERS. (Brown, 1944b).

Kind of Seed	Amount produced, lb.		Carry-over, lb.		Prices* to growers, per 100 lb.	
	1942	1943	1942	1943	1942	1943
					Dols.	Dols.
Sweet clover	29,088,000	21,420,000	11,996,000	8,862,000	6.82	9.72
Hairy vetch	32,020,000	21,680,000	2,840,000	11,170,000	10.00	11.90
Alfalfa	47,826,000	56,034,000	13,216,000	4,999,000	26.66	32.67
White clover	1,890,000	2,080,000	891,000	594,000	40.50	a43.15
Alsike	12,228,000	11,826,000	5,873,000	2,723,000	19.80	27.05
Red clover	49,728,000	56,028,000	40,232,000	23,276,000	19.28	30.17
Lespedeza	135,969,000	129,671,000	19,075,000	8,718,000	5.86	9.71
Austrian winter peas	133,300,000	154,000,000	1,643,000	61,093,000	5.00	5.00
Ladino clover	360,000	345,000	206,000	61,000	b70.00	125.00
Crimson clover	17,080,000	14,140,000	3,564,000	6,302,000	10.70	10.70
Sudan grass	37,300,000	30,900,000	25,652,000	8,510,000	2.60	7.15
Timothy	69,408,000	62,127,000	15,433,000	32,720,000	4.56	5.44
Redtop	16,600,000	10,300,000	13,837,000	13,476,000	6.40	14.30
Ryegrass	33,300,000	26,800,000	8,769,000	9,467,000	5.00	7.90
Orchard grass (Cocksfoot)	6,090,000	5,726,000	434,000	270,000	20.05	24.80
Bromegrass	8,902,000	6,885,000	2,159,000	4,147,000	...	12.35
Kentucky bluegrass	33,162,000	10,800,000	10,265,000	19,466,000	5.60	c10.35
Meadow fescue	1,225,000	1,175,000	185,000	182,000	7.00	12.70
Crested wheatgrass	12,008,000	3,883,000	987,000	862,000	...	9.70
Bermuda grass	865,000	1,000,000	...	16,000	...	...

* Best available average prices and therefore subject to variation for any particular locality.

a. Wisconsin.

b. Oregon.

c. Cured price.

CAUSES OF SEED SHORTAGE

The present shortage is due to a complex of factors and is aggravated by the war. Foreign supplies have been cut off. Seed figures amongst lend-lease requirements. During 1942, Russia and the United Kingdom were the two heaviest users of forage seed, each taking over 14,000,000 lb.; Russia needed vetches, alfalfa, alsike, red and crimson clovers, brome, orchard, timothy crested wheat and perennial ryegrass; the United Kingdom required alsike

red and crimson clovers, orchard and timothy grasses. In 1943, Russia asked for vegetable, not forage seed, and the United Kingdom asked for 19,000,000 lb. forage crop seed, orchard, meadow fescue, Kentucky bluegrass, timothy, alsike, and red clover, common vetch and fodder maize. She was allotted 12,000,000 lb. Grover Brown (1944b) says " It is unfortunate that our supplies are insufficient to meet our needs plus those of our allies, because in terms of food units, a great deal more can be shipped as seed than can be shipped in the same space as processed foods." He states, however, that though lend-lease has to some extent cut into the national supplies of forage crop seed, it has not materially affected the supplies available for home consumption.

Another wartime factor causing a scarcity of herbage seed is the high target set for meat and dairy products in the food production campaign. The achievement of this target requires an increased livestock population, a greater acreage for hay and fodder, and an increased supply of seed for pastures and forage crops. But since hay and fodder are commanding a far higher price than their seed, there is a bigger incentive to produce them, and the acreage formerly allotted to seed production is willingly cut down. Hay and other fodder crops, and oil plants such as soybean and peanut, all act as competing crops. This short-sighted policy satisfies the immediate needs only. It is hoped that the price support which has now been offered for seed production may help to remove the danger from competing crops.

Owing to the scarcity of commercial nitrate fertilizers now used for explosives, legumes are being increasingly used as a source of nitrogen for replenishing the soil with this element. Some idea of the quantity of legume seed required for this purpose may be gained from the estimate of an ammunition manufacturer. " Every time a 16-inch gun is fired, 100 pounds of nitrogen goes back into the air from which it came," which , according to Aamodt (1942/3) "is about all the nitrogen there is in about 600 pounds of nitrate of soda, or in two or three acres of vigorous leguminous plant."

The establishment of turf on airports and other military grounds is using up seed of the native grasses of the Great Plains, for example, buffalo grass (*Buchloë dactyloides*) and the gramas (*Bouteloua* spp.). These grasses have been used for conservation plantings on arable range lands since 1934 ; previously, their seed had not been collected or used extensively, and there are no stocks on hand.

In addition, reserve stocks of seed must be built up for the rehabilitation of regions which have suffered under the scorched earth policy and for other liberated territories, the food supplies of which have been depleted.

Further, this year's shortage has been accentuated by the severe winter-killing during 1943, which not only reduced seed yields but also made much reseeding necessary.

But the present shortage is not due only to wartime demands. There are causes of a more permanent nature. These are largely connected with the increase in grass seedings for one purpose or another. The revegetation of abandoned cropland is using up enormous quantities of seed. It has been estimated that in soil conservation Region V (Fig. 1) which includes Kansas.

Nebraska, North and South Dakota, Montana and Wyoming, the region where soil conservation work began in 1935, 12,000,000 acres of abandoned cropland have to be revegetated. Natural revegetation would take from 5 to 30 years to accomplish, far too slow a process to be of immediate benefit. Reseeding of such areas is, therefore, essential. In the Northern Great Plains, 5,000,000 acres of abandoned cropland have been reseeded since 1935.

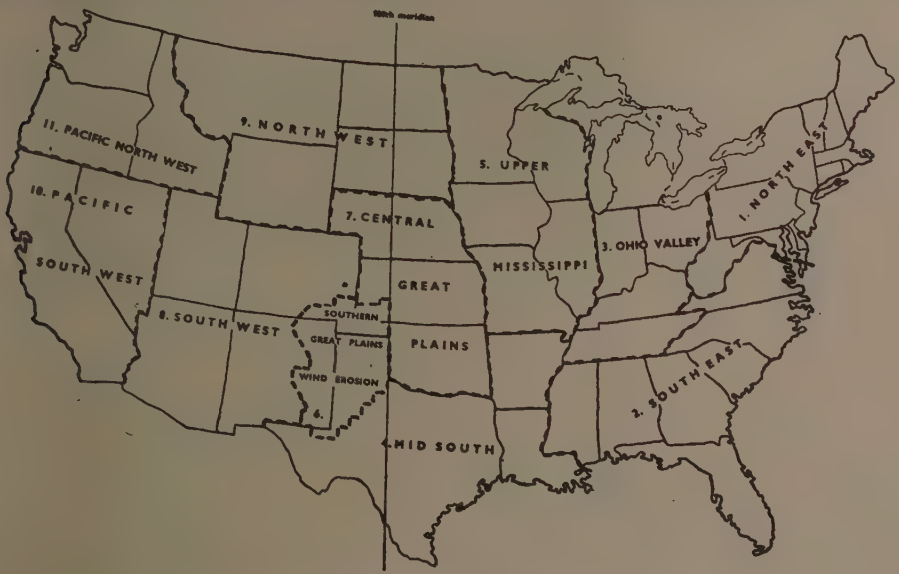

FIG. 1.—REGIONS OF THE SOIL CONSERVATION SERVICE

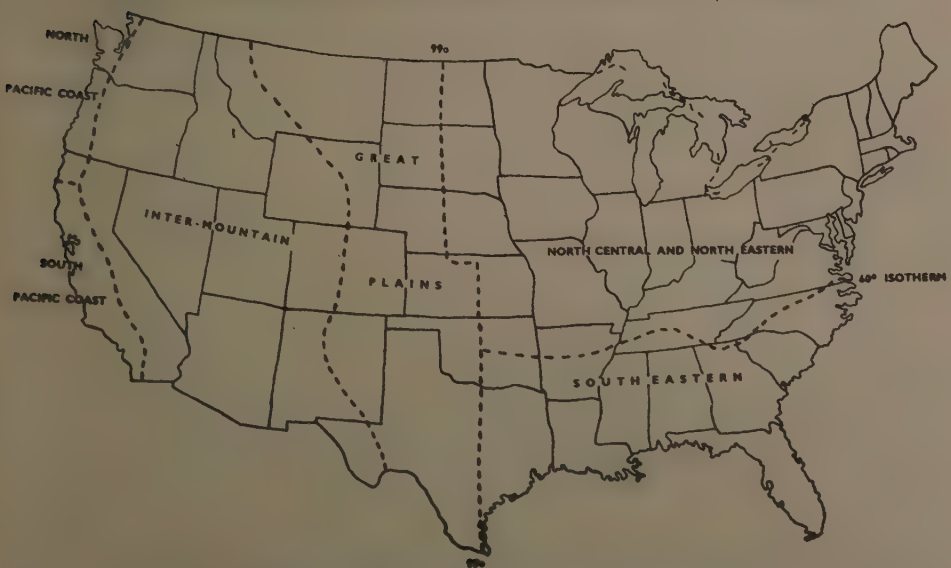

FIG. 2.—PASTURE REGIONS OF THE UNITED STATES

Conservation methods of farming which include the grassing of waterways, gully banks and terrace outlet channels, and the use of grass in crop rotations, all make heavy demands on grass seed. These methods, having proved their worth, have come to stay. More grass is also needed for reserves of hay, for ensilage material, for green manure, and in the control of noxious weeds. Seed supplies for certain civilian requirements, such as golf courses, parks, etc., have been reduced to *nil*, but these will be revived in the post-war years and create a further demand on the market.

Collins (1943) says that the demand for the seed of native and adapted tame grasses is so great that seed dealers cannot supply more than 50 per cent of the seed requested, and of the more valuable grasses less than 5 per cent. On the other hand, C. B. Mills (1944), president of the Ohio Seed Dealers' Association, states that from all indications there will be enough seed of most varieties to go round, and that the seeds which are not plentiful are those which have been subjected to excessive export ; they are alfalfa, alsike and red clover and orchard grass.

Regions of Production

" Specialized grass seed production in the United States is localised in the Pacific Northwest [Fig. 2]. No generally accepted special technique for culture has been developed elsewhere and few attempts have been made to encourage specific attention to production. In other regions much of the seed is harvested from established pastures or hay fields, and these may be nearly pure stands or mixtures of grasses and legumes " (U.S.D.A., 1943).

Most of the winter cover crop seed is produced in the Pacific Northwest and is shipped to the Southeastern States where it is needed for soil building. Winter cover crop seed (Austrian winter peas, vetches, crimson clover, lupin and ryegrass) was in good supply in 1942. Production amounted to 250,000,000 lb., a total which exceeded the set goal. This high point in production (chiefly Austrian winter pea) resulted from increased acreages encouraged by guaranteed minimum prices and also from higher yields per acre.

The State of Oregon specializes in cover crop seed ; some species are grown in one county, some in another ; in fact, the United States nation has depended primarily on Oregon farmers for its supply of vetch and pea seed. Grass seed is produced in the western part of Oregon.

In recent years, acreages and yields of grass and cover crop seed have been substantially larger and farm income has increased correspondingly. In 1942 the income was 90 per cent more than in 1941, and nearly three times the 5-year average from 1936 to 1940. Alfalfa has been the exception ; in this case acreage has been greatly reduced partly because of the disappointing yields resulting from grasshopper damage and heavy rainfall, but also because a higher price can be obtained for alfalfa hay. Table 2, taken from a yearbook prepared by the Oregon State College and United States Department of Agriculture, analyses the acreages harvested and the income obtained from cover crop seed during the years 1938 to 1942 inclusive.

TABLE 2. FORAGE CROPS SEEDS: ACREAGE HARVESTED AND CASH FARM INCOME, OREGON, 1936-1942.

(Oregon State College, 1943.)

Group and Item.	1936	1937	1938	1939	1940	1941	1942p
Pea and vetch seed.							
Acres	78,100	65,550	71,200	98,400	197,350	230,500	288,000
Dollars	1,162,000	1,434,600	1,074,000	1,648,700	3,676,000	3,137,000	7,910,0000
Clover seed.							
Acres	21,310	50,300	51,155	40,415	43,200	45,025	48,350
Dollars	928,500	2,035,600	1,082,200	1,151,900	898,700	1,355,000	1,597,000
Alfalfa seed.							
Acres	6,400	7,700	9,600	12,000	9,600	6,000	5,000
Dollars	155,000	303,000	234,000	213,000	165,000	97,000	112,000
Grass seed.							
Acres	31,990	30,975	58,240	72,270	92,270	98,990	113,500
Dollars	839,000	679,700	1,117,200	664,600	1,471,000	1,897,000	2,616,000
TOTAL.							
Acres	137,800	154,525	190,195	223,085	342,420	380,515	454,850
Dollars	3,084,500	4,452,900	3,507,400	3,678,200	6,210,700	6,486,000	12,235,000

p=Preliminary.

The Northern Great Plains area produces seed of the native grasses, the more important of which are western wheat grass (*Agropyron smithii*), blue grama (*Bouteloua gracilis*), bluestem (*Andropogon* sp.), dropseed (*Sporobolus* sp.) and buffalo grass (*Buchloë dactyloides*). Since 1936, the Soil Conservation Service has made extensive collections of seed of these grasses and is increasing the seed in nurseries. Under cultivation, yields are high, some species giving two seed crops annually.

Local production of seed by farmers is being fostered by the Soil Conservation Service. The seed production campaign launched by the soil conservation districts has achieved outstanding success. H. H. Bennett (1944), Chief of the Soil Conservation Service, says "The Holmes County, Mississippi, Soil Conservation District, for example, collected 1,623,020 pounds of seed of fifteen grasses and legumes in 1942. Five years ago not one pound of seed of these same grasses and legumes was collected in that county. This same kind of thing is going on in Georgia and in the other Southern States. The districts are doing a valuable service in pushing the pasture and seed collection phase of their conservation work."

The Department of Agriculture is supporting this policy by issuing advice to farmers on cultivation and harvesting methods for seed production. Recent developments in seed-harvesting equipment make seed production a profitable addition to a farm income. It can be practised alongside production for pasture, hay and silage.

Apart from the seed shortage there are other strong reasons for a wide distribution of seed producing areas. For example, there is a great need of legume cover crop seed in the Southeast. Most of the seed is produced in the Pacific Northwest and sent across country to the Southeast. The interval

between harvesting in the Northwest and planting in the Southeast is so short that much of the seed must be held over for the following season. Storage accommodation is then needed, and, to the cost of transport is added that of storage. Though soils of the Southeast such as those found in North Carolina are not naturally suited to seed production because of their low boron content, applications of borax make possible the production of legume seed on these soils. Seed of crimson clover, bur clover, blue lupin, vetches, crotalaria and wild peas can all be produced in the Southeast for use in the Southeast. Seed can also be produced in irrigated areas by regulating the flow of water so that vegetative growth is slow ; this favours seed setting.

Importance of Adapted Seed

The loss to the United States which has been incurred through the use of unadapted seed is another cogent reason for having numerous centres of plentiful production and for production " on the spot". " The term ' adapted grasses ' . . . is the key to the producers' and dealers' responsibilities to their customers. . . . It is of utmost importance that native grass seed be labelled according to source, or area where it was harvested, so that it will go only to areas where it is known to be adapted " (Collins, 1943).

The range of adaptability of grass seed is limited. Blue grama (*Bouteloua gracilis*) harvested in Texas, is winter-killed when sown in the Northern Great Plains ; if harvested in North Dakota it is not suitable for growing in Southern areas because it is adapted to a short, not a long growing season, to low, not high temperatures. Other native grasses which behave similarly as regards adaptation are switch grass (*Panicum virgatum*), big bluestem (*Andropogos furcatus*), sideoats grama (*Bouteloua curtipendula*), buffalo grass (*Buchloë dactyloides*), and sand bluestem (*Andropogon halii*).

Seed of bromegrass (*Bromus inermis*) is an example of an adapted tame grass. Seed from Canada, though of excellent quality and a good grower in Canada, gives poor yields of forage when grown as far south as Kansas or Nebraska. It is hard to start and is easily killed by hot weather. It has been suggested that seed produced north of latitude 42° should be planted in the North, that produced south of latitude 42° should be planted in the South.

Red clover (*Trifolium pratense*) offers another example of the value of adapted seed. The State College of Pennsylvania recognized that it is natural for regional strains to develop which have definite characteristics and are adapted to different climatic conditions. Accordingly, they conducted tests over a number of years to determine the weight of forage produced from seed originating from different sources. Seed was tested from European countries, from all parts of the United States and, more recently, from different counties within the State of Pennsylvania. Italian seed was worthless. French and Central European seed gave 60 to 80 per cent the amount of hay produced by domestic seed. The best domestic (i.e., U.S.A.) sources were Ohio, Illinois, Indiana, Iowa, Michigan, Wisconsin, and Minnesota ; Oregon seed was not so good. Of the local Pennsylvanian strains, several which had been grown on one farm or community for 10 years or longer have been more disease resistant, winter-hardy, persistent, and productive than other strains tested.

Although red clover is the most important legume forage crop in the State of Pennsylvania, only a small proportion of the necessary seed is produced in the State. The average annual requirement of seed is 7,000,000 lb., but the average annual production within the State is less than 900,000 lb. The results of the tests reported above justify a much wider acreage being devoted to red clover seed production in this State.

Alfalfa (*Medicago sativa*) seed is very sensitive to climate ; hence the use of adapted seed is particularly important. There is a surplus of seed for the southern region, just enough for the central region, but a shortage of northern adapted seed. Because susceptibility to difference in climate was not appreciated, seed was moved north, and there were many failures due to winter killing during the winter of 1942-43 in the central and northern regions.

The best, hardy, northern-adapted varieties are the variegated ones, for example, Ranger, Ontario Variegated, Cossack, Hardigan, Baltic, Grimm and Ladak. In view of the shortage of these varieties, particularly the new wilt-resistant Ranger, the question of growing these northern-bred varieties in the South for seed to be used in the North is being considered. It is thought unlikely that the genetic quality would degenerate for at least the life of the original planting of northern seed in the South. The North would benefit by a more plentiful supply of this seed, and the southern seed growers would find it a profitable undertaking since certified northern-adapted seed is at present about 14 cents per pound more than southern-adapted seed.

So much southern-grown seed was sent to the North that a seed shortage was proclaimed in the South. " To satisfy this condition, some 2,700,000 pounds of Argentine seed were imported for use south of 38° latitude. Such a situation can be the result of poor planning on the part of seed dealers, or it can be created purposely to take advantage of a price differential on imported seed. For example, the price of Argentine seed laid down in this country was approximately 16 cents per pound to the wholesaler and could be sold at 31·9 cents wholesale or 42·9 cents retail, the same as allowed for southern-produced seed—a possible margin of about 28 cents per pound. Restriction of imports of Argentine seed until there is a real shortage in the areas where such seed is adapted, is being seriously considered " (Brown, 1944b).

Position Regarding Other Species

Sweet clover (*Melilotus alba* and *M. officinalis*). Though a very valuable pasture legume, seed production in 1943 was considerably below that of 1942 and only about 40 per cent of the average annual production in the 5-year period 1937-1941. It is likely to be in great demand in the Southwest for the revegetation of eroded cultivated land. It is an excellent pioneer crop for wartime because, while it is building up the soil and preparing the way for future grass seedings, the land does not go out of production. Even in the first 2 years the sweet clover can be grazed and harvested for seed, thus providing a cash crop.

Ladino clover (*Trifolium repens* var. *latum*). This is another valuable pasture plant of which seed is very scarce. New York State alone needs more

ladino seed than was produced in the whole country during either 1942 or 1943. The production in these 2 years was below the annual average for the 5-year period 1937-1941. In fact, in 1943, seed production fell short of the objective by 75 per cent. The high price offered for hay was largely responsible for the large reduction in seed acreage in 1942 and 1943. But there is a more serious reason. In California, common white clover (*T. repens*) is contaminating fields of ladino clover to such an extent that certification is out of the question.

Lespedeza. Seed of the several species of lespedeza is being multiplied in nurseries of the Soil Conservation Service. *L. hedysarioides*, which was substituted by Japanese seedsmen in place of an order for *L. bicolor*, has shown great promise for soil conservation purposes. In 1943, 5,490 lb. of seed, and since 1936, a total of 42,500 lb. of seed of this species has been produced and distributed to farmers co-operating with districts. The seed is now on the commercial market. Seedlings as well as seed of the large bush lespedezas are being produced. During 1942-43, 600,000 seedlings and 6,165 lb. of seed of *L. bicolor*, *L. cyrtobotrya* and *L. thunbergii* have been produced in the South east and distributed to farmers.

Lupinus. The lupins have not been a great success in the United States. Commercial plantings have succeeded only in the Gulf coast area, *Lupinus albus* in the Mississippi Delta and *L. angustifolius* on the Coastal Plain soils. Approximately 10,000 acres were planted to this crop in the United States in 1942 and about 1,900 acres were harvested for seed.

Other legumes have already been referred to.

Sudan grass (*Sorghum sudanense*). A plentiful supply of this seed is necessary because Sudan grass is one of the most valuable summer pasture and hay plants. It is an annual, and is particularly important during drought periods; since these periods cannot be predicted, seed supplies must be at hand. There is nothing approaching the amount of seed required for 1944 summer plantings, supplies being 20,000,000 lb. less than for 1943 plantings; again, seed production in 1943 was only 60 per cent of the objective, and 7,000,000 lb. less than in 1942; further, during these 2 years, 1942 and 1943, production was far below the average for the 5-year period 1937-41. The seriousness of the progressively deteriorating seed situation is reflected in the difference in price charged to the grower in November, 1942 and November, 1943. The figures are $2.60 and $7.15 per 100 lb. of clean seed. It is hoped to bring the seed supply for 1945 up to the average annual figures.

Bromegrass (*Bromus inermis*). The use of this grass has spread rapidly, particularly in the northern areas where it is replacing timothy; yet, in 1943, the seed produced was only 49 per cent of estimated requirements. Formerly, bromegrass seed was produced in the Dakotas and in Manitoba and Saskatchewan, but now the seed is produced wherever it is adapted. The importance of knowing the source of bromegrass seed and of using adapted seed has already been mentioned. A lack of Lincoln type, Auchinbach and Fisher strains is retarding seedings. In 1943, Lincoln type was selling at 25 cents per lb. in Nebraska.

Timothy (*Phleum pratense*). All states in the upper Mississippi valley produce timothy seed. It is one of the most reliable grasses for seed production and is being encouraged.

Kentucky bluegrass (*Poa pratensis*). The seed may be harvested wherever the grass is grown.

Redtop (*Agrostis stolonifera major*). It is grown for seed mainly in Illinois.

Orchard grass (*Dactylis glomerata*). Most of the seed is harvested in a few counties in Kentucky, Indiana, Ohio, Virginia and also in southern parts of Illinois and Missouri.

Buffalo grass (*Buchloë dactyloides*). This grass is needed in Nebraska, Kansas, Oklahoma, Texas, Colorado and New Mexico. At present, with very little seed available, the price is $1.25 per pound. It is expected that there will soon be abundant supplies of this grass because a technique has been developed at Hays Experiment Station, Kansas, whereby 4,000 lb. seed per acre has been produced. Hitherto this grass has been difficult to harvest due to its peculiar seed-forming habits and prostrate growth.

Sideoats grama (*Bouteloua curtipendula*). Though a high seed yielder, it has been impossible to purchase seed of this grass commercially. New improved strains have been developed by the Soil Conservation Service. Only adapted seed is recommended.

Bluestem (*Andropogon* spp.). Sand bluestem (*A. halii*), East Indies bluestem (*A. ischaemum*), and Australian bluestem (*A. intermedius*) are not available commercially. Sand bluestem is badly needed in some sandy areas and the demand for big bluestem (*A. furcatus*) exceeds the supply. It is important to know the origin of bluestem seed.

Sand lovegrass (*Eragrostis trichodes*). This is a very palatable grass well adapted to sandy areas in Nebraska and Kansas. In 1943, no seed was available through dealers ; it can, however, be produced profitably in pure stands.

Russian wild rye (*Elymus junceus*). This is a hardy bunch grass which was released about 1940. No seed was located commercially in the autumn of 1943 even though $1 per pound was offered.

Western wheatgrass (*Agropyron smithii*). There has been very little seed of this grass available, yet in 1942 millions of pounds of seed in the Northern Great Plains was left unharvested. Since it is found growing in pure stands from Montana to Arizona, and can be harvested with the combine, it lends itself to harvesting by farmers.

Crested wheatgrass (*Agropyron cristatum*). This is a grass with a future in the Northern Great Plains area. It is able to grow well under limited rainfall, and has a high carrying capacity. Consequently, the demand for seed is increasing, but the 1943 production reached only 38 per cent of the set goal ; this was partly attributable to unfavourable weather. Imports from Canada have continued, thus providing a plentiful supply in some parts. This grass is adapted to a rather limited area.

Intermediate wheatgrass (*Agropyron intermedium*). There is no seed on the market, though there is a good demand for the seed for the purpose of grassing gullies and waterways.

Feather bunchgrass (*Stipa viridula*). This is another good grass for the Northern Great Plains, but with no commercial source of seed.

* * * *

In view of the large number of useful grass species of which seed is not yet commercially available, and because of the more varied purposes for which grasses are used now that conservation methods of farming have been adopted, it is considered that there should be wider and more lasting opportunities for seed producers and dealers, especially those who set out to supply the more specialized grasses.

The farming community remains by far the biggest market for herbage seed; the federal government makes relatively small purchases. In 1942, the Soil Conservation Service bought only 200,000 lb. seed from dealers for all its work in connexion with the regrassing of government-owned land, demonstrations of soil conservation methods of farming, and its nursery trials. This is a very small proportion of the millions of pounds of seed required annually by farmers.—D. BROWN.

BIBLIOGRAPHY

1. AAMODT. O. S. 1942. Seed situation and the war. *Seed World*. 52. No. 11. 10-11 and 18-19.
2. ———————— 1943. Seed situation and the war. *J. Amer. Soc. Agron.* 35. 85-91.
3. BENNETT, H. H. 1944. Kudzu-Power Plant of South's new agriculture. *Soil Conserv.* 9. 171-5.
4. BROWN, G. F. 1944a. Committee on seed production program. *Soil Conserv.* 9. 147 and 160-1.
5. ————————1944b. Where shall we get the seed? *Soil Conserv.* 9. 183-5. and 190.
6. COLLINS, W. 1943. New opportunities for seedsmen in grass seed market. *Seed World*. 54. No. 12. 10-13.
7. IMPERIAL BUREAU OF PASTURES AND FORAGE CROPS, ABERYSTWYTH. 1937. Collection of native grass seed in the Great Plains, U.S.A. By Crider, F. J., and Hoover, M. M. Bull. No. 24. pp. 15.
8. MCKEE, R., and RITCHEY, G. E. 1944. Nature and uses of lupine plant. *Seed World*. Vol. 55. No. 5. 8-9.
9. MILLS, C. B. 1944. Stocks and prospects for grass seed in 1944. *Seed World*. 55. No. 5. 38 and 40.
10. OREGON STATE COLLEGE, 1943. Oregon's forage seed crops. 1941-42. Statistical Year Book. By Thomas, M. D., Breithaupt, L. R., and Nielson, N.I. Extension Bull. 613. pp. 23.
11. PENNSYLVANIA AGRICULTURAL EXPERIMENT STATION. 1943a. Local, domestic and foreign red clover seed. By H. B. Musser and J.K. Thornton. Bull. 458. pp. 16.
12. ———————————————— 1943b. Alfalfa varieties and seed sources. By H. B. Musser and J. K. Thornton. Bull. 459. pp. 5.
13. PILAND, J. R., IRELAND, C. F., and REISENAUER, H. M. 1944. The importance of borax in legume seed production in the South. *Soil Science*. 57, 75-84.
14. TABOR, P. 1944. Speeding production of new plants for soil conservation. *Soil Conserv.* 9. 178 and 186.
15. UNITED STATES DEPARTMENT OF ARGICULTURE. 1943. Grass seed production. By M. A. Hein. AWI-43. pp. 11.
16. UNITED STATES DEPARTMENT OF AGRICULTURE, SOIL CONSERVATION SERVICE. 1943. Reproduction and harvesting of legume and grass seeds in 1943. Mimeogr. pp. 8.
17. YOAKUM, K. 1944. Sweetclover's unique role in Southwest. *Soil Conserv.* 9. 187-9.

REGRASSING IN THE CANADIAN PRAIRIES

The Prairie Farm Rehabilitation Act was passed by the Dominion Parliament in April, 1935, with the object of assisting prairie farmers to combat the combination of drought and economic depression which was seriously affecting agriculture at that time. A publication giving a record of achievements to date has recently been issued, covering the 8-year period ended March 31, 1943 (Canada, Dept. of Agric. P.F.R.A. A record of achievement ; Ottawa, 1943, pp. 78). The chief improvements in prairie agriculture initiated by the P.F.R.A. are concerned with the control of soil drifting, the better utilization of land, and the conservation of water for farm purposes.

The true prairies or grass-covered plains of Canada form a rough triangle, the base of which extends from southwestern Manitoba through Saskatchewan to southwestern Alberta, and with its apex reaching roughly to within 60 miles south east of Edmonton, Alberta. East, north and west of this triangle the plain is wooded, the transition between grassland and woodland being gradual.

Scanty precipitation is the principal factor controlling the distribution of native vegetation and of crops. The average annual precipitation ranges downwards in a westerly direction from 19·8 inches at Winnipeg, Manitoba, to 12·8 inches at Medicine Hat, Alberta. Precipitation also decreases northwards, the average annual amount at Fort Vermilion, Alberta, being only 11·8 inches. The efficiency of rainfall in plant growth is, however, somewhat greater in the Fort Vermilion area than at Medicine Hat, because of lower evaporation arising from lower temperatures in the north. The prairie climate is described as sub-humid and in some regions semi-arid ; most of the precipitation is received during the summer. The climate is further characterized by warm summers and cold winters, and by wide extremes in temperature.

The combined effect of precipitation on the amount of moisture available for plant growth has a profound influence on native vegetation and cropping possibilities. In the south-central section of the Prairie Provinces, where high summer temperatures reduce by evaporation the effectiveness of the relatively light rainfall, the native vegetation is largely confined to short grasses and small drought-resistant plants, and agriculture to a rather hazardous production of cereals or to cattle ranching. Outside the " short grass " area, a more favourable balance between rainfall and evaporation results in a " tall grass " vegetation, with scattered clumps of woodland. Crop production in this area is less hazardous than in the " short grass " area, but it is still largely limited to cereals. The foregoing two vegetational zones constitute what is generally referred to as the prairies. Beyond these zones the influence of relatively high rainfall or of lower evaporation has favoured the natural establishment of forests which extend across the northern reaches of the Prairie Provinces. Crop production in the southern fringes of the wooded areas covers a wider range of crops than in the prairies, but is subject to greater danger from frosts.

The outstanding characteristic of prairie soils as a whole is their high inherent fertility, the limiting factor in crop production being moisture rather than plant nutrients ; these soils exhibit to a marked degree the influence of climate and vegetation, modified locally by topography and texture. The

southeastern grass region is known as the " Brown Soil Zone " ; outside this region is a zone varying in width from 40 to 80 miles, where soils of a dark brown colour reflect the influence of more favourable climatic conditions, and where much of the best wheat land is to be found. East, north and west of the dark brown soil zone occurs a belt of black soils corresponding roughly to tall-grass parkland ; the most fertile farmland, although not necessarily the best wheat land, occurs in this zone. Beyond the black zone, the soils grade off through a transitional zone to the grey wooded soils of the northern forest. These soils are subject to relatively heavy leaching, but their fertility can be maintained by fertilizer, cultivation of legumes, and application of sulphur.

The south-central region of the Prairie Provinces experienced an almost unbroken succession of dry years during the period 1930 to 1937, and fully one-third of the cultivated land in the open plains was affected by soil drifting, in many districts with a permanent reduction in fertility. It was during this period that the Prairie Farm Rehabilitation Programme was developed, with the three main objects :

(*a*) cultural : to secure the adoption by farmers of such tillage and cropping practices as would enable them to farm successfully under a wide and fluctuating range of physical and economic hazards ;

(*b*) land utilization : to divert crop production from poor land and to use such land for grazing ;

(*c*) water development : to make better use for agriculture than formerly of the limited water resources of the prairies.

The bulk of soil drifting occurs on summer fallow land, and it is through adjustments in the practice of fallowing (strip farming—alternate crop and fallow, the ploughless fallow and trash cover, and the use of cover crops by autumn sowings of spring cereals) that the principal measures of control are effected. On sub-marginal areas, and particularly on very light soils, the re-establishment of the grass cover appears to be the only feasible course.

The following technique for the reclamation of bare drifted land has been found to be satisfactory, and has been used to reclaim some of the worst examples of soil drifting in Western Canada.

(1) Listing to produce a corrugated surface is the most effective method of stopping drifting on bare land.

(2) Seeding spring or autumn rye, according to season, on listed furrows is a most effective method of establishing vegetative cover on bare land. This seeding is done when temperature and moisture will promote rapid germination. Best results have been secured by broadcasting the seed over the furrows, growth on the top of the listed ridges having shown a marked effect in checking drifting. Plants growing only in the bottom of listed furrows have frequently been destroyed by drifting from the exposed ridges. Where the land is very susceptible to wind erosion it has been found advisable to leave the mature rye crop unharvested. In milder cases the crop has been harvested, thereby repaying some of the cost of reclamation.

(3) The final stage in the process of reclamation is to re-establish crop production under strip farming, and with proper tillage practices, or to seed the land down to permanent grass. On the majority of reclamation projects the latter course has been preferred.

The function of the cereal crop in regrassing work is to shelter tender grass seedlings from drifting soil and excessive heat. In many localities drifting soil may be stabilized by a heavy growth of weeds, notably Russian thistle (*Salsola pestifer*); it has been shown that grasses, and particularly crested wheat grass (*Agropyron cristatum*) can be successfully established in a stand of Russian thistle and will eventually replace the thistles. Some 800 regrassing projects, both experimental and demonstrational, have been located throughout the drought areas, and thousands of prairie farmers not formally experienced in the cultivation of grass on submarginal land have learnt the best methods for regrassing under a wide range of conditions.

Regrassing Technique

Brome grass, while not so satisfactory as crested wheat grass on the Brown soils, is probably the better grass on Black soils. The value of brome as a trap crop for wheat stem sawfly justified its use in areas infested with this pest, even where crested wheat grass would give better yields. A new strain of brome grass, named Parkland, has been introduced by the Experimental Farms. Parkland differs from common brome grass in that it does not possess the objectionable creeping rootstalks of the latter.

Alfalfa and sweet clover are the principal legumes grown in the Prairie Provinces. Neither of these crops, however, has given good results on dry upland soils, but they have proved useful in low moist areas. In general, sweet clover is more dependable, if less desirable, than alfalfa. Sweet clover, together with brome, is suitable for growing on alkali land.

For sloughs on which water lies for part of the season, reed canary grass is satisfactory, while redtop, brome and alsike grow well on slough margins.

Dates of Seeding: The best time to seed grass on dry land has proved to be in the late autumn or early spring. Fair results have been secured with early autumn seeding, but very poor results with summer seedings. With alfalfa and sweet clover, the best results have been secured by seeding in early spring.

Methods of Seeding: As a general rule, grass sown on prairie land should be sown with a seed-drill, on soil protected by long stubble, or weeds. Seeding with a nurse crop, as is done in humid regions, is not satisfactory on dry land. Broadcasting the seed has not given satisfactory results, nor has any method of seeding on bare land.

As regards the rates of seeding, P.F.R.A. experiments indicate that good stands of crested wheat grass may be secured by seeding in drills 12 inches apart at from 5 to 7 lb. per acre. Heavier seedings give thicker stands, but in a few years no difference can usually be observed between light and heavy seedings of crested wheat grass.

Production of Seed of Adapted Species

With the object of promoting a wider use of cultivated grasses by prairie farmers, and especially of increasing the supply of seed of suitable species, particularly crested wheat grass, members of Agricultural Improvement Associations have been assisted in establishing grass seed plots. To this end small plots of grass and other forage seed, sufficient to sow from 2 to 5 acres, have been distributed by the Dominion Experimental Farms to all interested A.I.A. members.

During the first 5 years of the operation of the P.F.R.A., some 40,000 small lots of grass and other forage seed were distributed to members of associations. The total amount of seed distributed was approximately 500,000 lb., consisting mostly of crested wheat grass, but with considerable quantities of brome grass and smaller quantities of slender wheat grass, sweet clover and alfalfa.

The results secured by A.I.A. members in starting grass seed plots have been variable, and subject to many hazards, principally drought and inexperience. It has been estimated, however, that successful stands of grass or hay have been secured on plots which in the aggregate cover some 50,000 acres. Approximately 2,000,000 lb. of crested wheat seed alone have been harvested from these plots, and the annual yield of seed, now that the plots are well established, will be greatly in excess of this figure. In view of the increasing demand for this seed, and of the insufficient supplies hitherto available, this phase of the P.F.R.A. programme serves a useful purpose. In conjunction with the regrassing experiments, moreover, it has resulted in the wide dissemination of methods of regrassing among farmers who have had no previous experience or even interest in this work.

Plant breeding problems in relation to forage crops for prairie agriculture are investigated at the Dominion Forage Crops Laboratory at Saskatoon, in co-operation with the University of Saskatchewan.

Community Pastures

The P.F.R.A. Community Pasture has become a well-known feature of agricultural organization through a large extent of the Prairie Provinces. Before a community pasture is established, a survey is made of the area to determine the possibility of securing control of the land, the degree to which the tract is unsuitable for cultivation, and the relation of the area to surrounding farm land. The nature and possibility of improving the grazing is determined by a grazing survey made by officials of the Experimental Farms. The principal object of these surveys is to determine the carrying capacity of range land, having regard to soil herbage, watering facilities and other considerations.

Once control of the land in a projected pasture is secured, the area is enclosed and suitably subdivided by strong fences provided with stock-watering facilities and corrals, and regrassed where advisable. When the pasture is ready for use, a pasture manager is appointed by, and is directly responsible to, the Land Utilization Branch of the P.F.R.A. Administration, and grazing

privileges are granted at reasonable fees to stock raisers in the vicinity. Community pastures serve mixed farming rather than purely ranching interests.

In order to facilitate adjustment of the details of management to suit local requirements, a Grazing Association of pasture clients has been organized in connexion with most of the pastures. The function of a Grazing Association, acting through an elected council of five members, is to assist the pasture manager in the allocation of grazing privileges, to determine what conditions shall govern the admission of livestock, to select the breed of male breeding stock, and generally to assist the manager in the conduct of pasture business. Ultimately it is hoped that the entire management of each pasture shall be assumed by the Grazing Association, subject only to the restriction that the land be kept out of crop production

The fees charged for grazing privileges on community pastures are based on estimated costs of operation and maintenance. The entire original cost of establishing pastures is borne by the government as a contribution to the improvement of land-use conditions on the prairies. It is thus possible to keep fees at a moderate level. During 1942, the monthly grazing fees ranged from 30 to 35 cents per head of cattle, from 40 to 50 cents for horses, while 5 cents was set as the charge per head for sheep.

Experience has shown that pastures in which less than from 15,000 to 20,000 acres can be supervised by one pasture manager are likely to be expensive in operation. This fact excludes smaller tracts of submarginal land from the community pasture programme. It has also been found that it takes almost 2 years to bring an average pasture into economical production.

Preliminary surveys have been made of seventy-five proposed new community pastures covering an aggregate of 1,573,840 acres. The development of these areas combined with the 1,261,100 acres already in existing pastures would result in the permanent removal from cultivation and the utilization under controlled grazing of a large acreage of submarginal land, and would represent a considerable contribution to the solution of land-use problems in Western Canada.—R. O. Whyte.

HILL SHEEP FARMING IN GREAT BRITAIN*

The Reports of two Committees set up to consider the present state and future prospects of this industry appeared early in 1944.* The Committee for England and Wales appointed by the Agricultural Improvement Council for England had the following terms of reference :

" To investigate the present position of hill and upland sheep farming in England and Wales, and in the light of modern scientific knowledge, to suggest measures which might be taken to improve the condition of hill and upland grazings, the health and hardiness of sheep stocks, and systems of management."

* England and Wales, Ministry of Agriculture and Fisheries, 1944. Report of the Committee on Hill Sheep Farming in England and Wales, pp. 40. [Cmd. 6496.] Scotland, Department of Agriculture, 1944. Report of the Committee on Hill Sheep Farming in Scotland, pp. 127. [Cmd. 6494.]

Shortly after its appointment, the Committee was requested to consider the following additional aspects :

(*a*) which land, from the point of view of hill sheep farming, could be most easily spared for afforestation, and.

(*b*) how the respective needs of forestry and hill sheep farming could be mutually adjusted so as to interfere as little as possible with the maintenance of hill sheep flocks and the improvement of hill sheep farming.

The Committee on Hill Sheep Farming in Scotland was to investigate the present position of hill and upland sheep farming in Scotland and to report what steps should in their opinion be taken with a view to placing this branch of the Scottish farming industry on an economic basis, and in particular to specify measures for improving the condition of hill and upland grazings, the health and hardiness of sheep stocks, systems of stocking and management, and marketing methods.

The Report for England and Wales divides the five million acres of hill and upland into four main areas : (1) the Cheviots and Pennines from the Border to S.W. Durham, (2) the Dales in S.W. Durham, N.W. Yorkshire and N.E. Lancashire, and the Peak district of Derbyshire, (3) the mountains and fells of Cumberland and Westmorland, and (4) the mountains and hills of Wales, West Hereford, and South-west Shropshire. In addition there are scattered areas in Cornwall, Devon and Somerset (Bodmin Moor, Dartmoor, and Exmoor), and in N.E. Yorkshire (Cleveland).

It is assumed that most farm crops can be grown with reasonable prospects of success up to an altitude of 600 to 800 feet. Between this altitude and 1,400 to 1,500 feet, where arable cropping and intensive livestock management become uneconomic, are the transitional areas known as uplands, the management of which varies from lowland to hill types of farming according to local conditions. Above 1,400 to 1,500 feet is the hill farming proper ; it is this area and the uplands worked on similar systems that are covered in the Report. It is not possible to state the exact acreage of hill farm land, but the Committee has adopted a figure of five million acres as a near approximation ; this represents about one-sixth of the total agricultural area of England and Wales. It was also found to be difficult to make an accurate statement of the number of hill sheep in the area under review, but of the total ewes (including shearlings and ewe lambs for service) in England and Wales immediately before the war between 20 and 25 per cent consisted of hill breeds kept on hill farms ; the area therefore carried between three and four million breeding ewes in 1939. On this sheep population the greater part of lowland sheep husbandry depended. The hills also maintained considerable but indeterminate numbers of cattle.

The broad impression created by this investigation of a substantial section of the agricultural industry and its people is one of " deplorable waste in human and material resources, following upon the many speculative shifts and changes to which hill farmers have been compelled to resort through years of continuing price instability and economic uncertainty." The Committee is satisfied that this waste can be arrested by the combined application of

scientific and practical knowledge, but these improvements cannot be regarded in any way as substitutes for a sound economic foundation to the industry. Science cannot take the place of a stable price system. " The overriding need is an economic context which will justify expenditure on the reconditioning and re-equipment of farms and the re-establishment of good standards in land and livestock husbandry."

First place in the Assisted Programmes that are recommended is given to the improvement of grazings and of the carrying capacity of hill pastures. This is essential in view of the fact that alternate husbandry and the use of new leys on an extended scale in the lowlands will call for more sheep and cattle from the hills ; hill and upland pastures will be needed to supplement the resources of lowland farms for the rearing of stock. All this can be done while maintaining a proper balance and co-ordination between afforestation and sheep farming.

The improvement of grazing, and in particular that of intakes is regarded as the most important single factor in the rehabilitation of hill farming. The work of Sir George Stapledon and the Cahn Hill Improvement Station and, more recently, of individual farmers and the War Agricultural Executive Committees has clearly indicated the possibilities of increasing production. The outstanding practical problem is the lack of balance between the stock-carrying capacity of the grazings in summer and the winter keep produced. There is too little of feeding value available at the time of greatest need. More winter keep for sheep and cattle must be provided by the intakes and lower enclosures, where deterioration is most pronounced and prospects of improved production are best. Ploughing and reseeding, either direct or after a pioneer crop, are recommended. When for some reason reseeding cannot be adopted, a useful amount of improvement may be obtained by liming, manuring and careful stock management. The general aim in pasture improvement in the hills and uplands must first be to increase fertility and second, by a combination of cropping and stock management, to conserve fertility. The cultivation of " removal " crops is not favoured.

The following are the other conclusions made, with special reference to improvement of grazings :

(1) the further breeding and production of strains of grasses, clovers, and other hill herbage plants, selected for their seasonal productivity and persistence under varying hill conditions, should be pressed forward ;

(2) the design and production of suitable power-driven drainage tools should have attention, and the experience of the Forestry Commission could be utilized with advantage ;

(3) both with lime and phosphates, experiments are needed to determine minimal dressings to suit varying conditions of deficiency ;

(4) cattle are regarded as a vitally important factor in the improvement of hill grazings ;

(5) the bracken problem is of such magnitude that more intensive research to find less laborious and cheaper control measures would be worth-

while. The ecology of the plant, chemical dressings, and the possibilities of commercial or agricultural use, all merit further investigation. Approved bracken cutting machines should be included in machinery pools formed for service in the hill areas ;

(6) heather should be managed by regular burning, which need not interfere with the interests of game ;

(7) in the past the approach to the problems connected with disease has been too narrow, and more attention should be given to comprehensive studies of methods to produce a greater degree of positive health as well as to detailed treatments for specific diseases. Research into problems of disease among hill flocks should be greatly extended, but the purely veterinary approach must be closely linked with studies in pasture improvement, breeding, and management.

The Report of the Committee on Hill Sheep Farming in Scotland is three times as long as that for England and Wales, and is divided into six sections, dealing respectively with the historical aspect, hill sheep farming to-day, the economic plight of the industry, the general conditions of the industry, the task of reconstruction, and the objectives of a long-term policy. Although hill sheep farming as an industry has shrunk to some extent since 1870, when it reached its zenith, it is still of supreme importance in Scottish agriculture. The area of 10,700,000 acres of land classified as " mountain and heath land used for grazing," together with a comparatively small acreage of land classified as permanent grass and arable land, is the basis of the Scottish hill sheep industry. This area carries about two and a quarter million breeding ewes and perhaps 100,000 cattle of all ages. The total number of sheep of all kinds carried in the summer time (including ewe hoggs and the annual crop of lambs) may be as much as four and a half million. In 1940-41 the number of ewes in hill flocks was almost 70 per cent of the total number of ewes in Scotland.

Hill sheep farming has been typical of the hill districts of the southern counties of Scotland for many centuries, but it was not until the latter half of the eighteenth century that south-country sheep farmers began to take over tracts of land in the Highlands and convert them into large sheep walks. This spread of large-scale sheep farming over land where the traditional use had been small-scale intensive subsistence farming, with a heavy population and high degree of subdivision of land, reached its peak about 1870. When the traditional type of agriculture had to give way to the new sheep ranching, it left behind it a great store of fertility in both low ground and hill. The pressure of population and the need for subsistence had resulted in the cultivation of all land of value, and, with the intensive labour and combined stocking with cattle, sheep, pigs and poultry, the conditions of the lower ground generally was one of high fertility. Although hill grazings were not cultivated in any way or even very much used, they too are believed to have been in a good state of natural fertility.

Hill sheep farming was extremely prosperous until about 1870, when there followed a long period of neglect parallel with the readjustments that become necessary with the imports of Merino wool and of meat, and the

demand of the public for smaller joints of meat. The first prosperous phase of hill sheep farming, particularly in the Highlands, was a period of " extractive " farming, of the gradual exploitation of the fertility to which the industry had fallen heir ; little was put back on the land, and the realization of the evil results came too late. This failure to preserve fertility and to carry out improvements in good times has continued up to the present day, and the accumulated neglect of several generations has now to be faced.

In making their recommendations, the Committee also consider the claims of other types of land use on the acreage under consideration, namely, deer forests, the planting programme of the Forestry Commission, and the creation of crofter holdings by the authorities concerned with the formation of new settlements on land formerly devoted to sheep farming in the Highlands and Islands.

The Committee consider that a comprehensive long-term policy is needed to bring the industry eventually to a position in which it can prosper without assistance. They state that, although independent action could be taken on many of their recommendations individually, they cannot emphasize too strongly that they have tried to provide not a selection of remedies but a coherent policy which requires application as a whole. The two basic objectives are : (*a*) the restoration of fertility on the hills and in the in-by land (intake), and (*b*) the encouragement of the return of skilled labour to the hill lands by creation of all suitable conditions. It is recommended (as the first of the Committee's twenty-five recommendations) that, until a long-term policy can be put into operation and begins to be effective, the industry should continue to be given such assistance as conditions may require in the emergency form of direct subsidy as at present. This should, however, be dispensed with as soon as possible.

It may be noted that the Scottish Report does not lay the same stress upon grassland improvement as the England and Wales Report, although there is a full discussion of the problems connected with heather burning as it affects sheep grazing and cover for grouse. It is also noted that neither Report gives any consideration to the relation between land use in hilly and mountainous regions and the erosion of soil, or to the relation between type and management of the vegetative cover and the conservation of water and flood control.—R. O. WHYTE.

THE SCIENTIFIC WORK OF R. D. WILLIAMS

Although Capt. R. D. Williams' work was almost entirely centred around leguminous plants, and the work in all its aspects was to him closely connected and related, it had at least two rather distinct aspects.

Before we can even attempt to evaluate this work, we must first of all recall that prior to 1919 the world's ignorance of the clovers was indeed profound. It is true that systematists had analysed the material down to the distinct species, and, in some cases, to varieties. Botanists might, however, smile at some of the attempts made by seedsmen to give " varietal " status

to some of their fancy lines, and especially to regard " White Dutch Clover " as *Trifolium repens* and the wild form of white clover as " *T. repens* var. *sylvatica*." In fact, practically nothing was yet known concerning the extent to which variation occurred within red clover (*Trifolium pratense*) and white clover (*T. repens*). It is true that certain general types of clover, such as the " Double-Cut " and the " Single-Cut " were widely recognized, and that certain local strains were also known, but little was understood concerning similarities and differences between such general types.

The study of type variation was an essential preliminary to any breeding work, but for this also it was necessary to study the flowering and pollination habits of the species, and to devise and develop a reliable and satisfactory breeding technique.

It was from this point that the work tended to diverge along two rather different lines, namely, the production of improved strains of the species in hand, and a far more intimate study of the plant material itself.

For the production of improved strains, a sound breeding technique is essential but equally important is sound judgment in the selection of plant material to form the basis of a strain. Then follow progeny tests and ultimately the technique of strain-building. In fact, so far, " plant breeding " in the sense of the production of improved strains remains an art and it was by the exercise of this art through all the stages of selection, breeding, re-selection and strain-building that enabled the late Capt. Williams to produce such well-known strains as S123 Red Clover and S100 White Clover, and his success as a clover breeder is abundantly exemplified in the success of these strains and their value in relation to increased food production.

While these strains are already well-known in many parts of this country and beyond, and especially amongst farmers and seed merchants, the other aspect of Capt. Williams' clover work is known mainly to plant geneticists. He realized that, while a great deal can be done towards the production of improved clover strains through the exercise of the art of plant breeding, the breeder must interest himself in the more intricate and fundamental problems that are ultimately involved. In the study of clover genetics, he was a pioneer. Here, again, he looked at the work from two different angles. In the one case, there was the general heterozygosity of the plant material and particularly the preservation of lethal and other defect factors in the heterozygous condition in ordinary clover populations. He made an extensive survey of plant material and identified a very large number of such "defective" or " deficiency " factors, particularly those which, in the homozygous condition, gave rise to many genetically different chlorophyll-deficients and dwarfs.

In addition, however, he interested himself in the more intensive study of particular characters and their mode of inheritance, such as flower colour, hairiness, leaf marking and so on in red clovers, and in later years he made a special study of the genetical causes of self- and cross-incompatibility in red clover. Unfortunately, his studies in this direction were cut short by the advent of the war, and finally by death itself, but he had already been able to show that incompatibility was determined by a very large number of

alleles. In a paper read at Edinburgh in 1939, he gave a brief account of this work and stated that " twenty-four plants of English late [red clover] variety and twenty plants of English broad red variety taken at random from commercial populations, were found to carry as many as 41 and 37 S alleles respectively."

The fruits of Capt. Williams' labours in the production of new clover strains are already providing an abundant harvest. Even the best strains, as he himself fully realized because he was endeavouring to produce still better ones, are liable to be superseded, and ultimately to be forgotten. In the genetical study of the clovers, however, the work that he accomplished will always remain, because it is fundamental in character.—T. J. JENKIN.

PUBLISHED WORKS OF R. D. WILLIAMS.

STAPLEDON, Reginald George, and WILLIAMS, Rhys David. The influence of the drought of 1921. Welsh Plant Breeding Station. Bull. Ser. H. No. 1. pp. 12-15. Aberystwyth, 1922.

————————, JENKIN, Thomas James, and WILLIAMS, Rhys David. Problems connected with the fertilization of the grasses and clovers. Welsh Plant Breeding Station. Bull. Ser. H. No. 1. pp. 16-21. Aberystwyth, 1922.

————————, and WILLIAMS, Rhys David. Seasonal productivity of the herbage plants in general use. Welsh Plant Breeding Station. Bull. Ser. H. No. 1. pp. 21-35. Aberystwyth, 1922.

————————, JENKIN, Thomas James, and WILLIAMS, Rhys David. Potentiality and nationality. (3) Legumes which are only productive in the seeding year, or if longer lived attain to their greatest productivity in the seeding year. Welsh Plant Breeding Station. Bull. Ser. H. No. 1. pp. 39-43. Aberystwyth, 1922.

———————————————— Potentiality and nationality. (4) Biennial and perennial legumes which are not used to any great extent in Central Wales. Welsh Plant Breeding Station. Bull. Ser. H. No. 1. pp. 43-45. Aberystwyth, 1922.

———————————————— Clovers which are extensively employed in Britain in the preparation of temporary and permanent grass. White clover : General. Welsh Plant Breeding Station. Bull. Ser. H. No.1. pp. 68-70. Aberystwyth, 1922.

————————, and WILLIAMS, Rhys David. Seed production. Welsh Plant Breeding Station. Bull. Ser. H. No. 1. pp. 88-91. Aberystwyth, 1922.

WILLIAMS, Rhys David. Depth of sowing grass and clover seeds. *J. Minist. Agric.* 29. 53-60, and 132-7. 1922.

———————— Clovers which are extensively employed in Britain in the preparation of temporary and permanent grass. Alsike clover. Welsh Plant Breeding Station. Bull. Ser. H. No. 1. pp. 67-68. Aberystwyth, 1922.

———————— Clovers which are extensively employed in Britain in the preparation of temporary and permanent grass. Red Clover : General. Welsh Plant Breeding Station. Bull. Ser. H. No. 1. pp. 74-83. Aberystwyth, 1922.

STAPLEDON, Reginald George, and WILLIAMS, Rhys David. Red clover. *J. Minist. Agric.* 30. 239-45. 1923.

WILLIAMS, Rhys David. Methods of covering grass and clover seeds. *J. Minist. Agric.* 29. 1125-1134. 1923.

ELLIS, V. S., and WILLIAMS, R. D. Growing red clover seed in Wales. *J. Minist. Agric.* 30. 533-5. 1923.

WILLIAMS, Rhys David. Methods of covering grass seeds. *J. Minist. Agric.* 30. 1134-1139. 1924.

———— The productivity of different strains and nationalities of red clover under hay and pasture conditions. Welsh Plant Breeding Station. Bull. Ser. H. No. 3. pp. 131-50. Aberystwyth, 1924.

————, and DAVIES, William. A note on subterranean clover (Australian variety). Welsh Plant Breeding Station. Bull. Ser. H. No. 3. pp. 151-158. Aberystwyth, 1924.

———— Grassland and the grazing animal. By R. G. Stapledon, T. W. Fagan and R. D. Williams. Welsh Plant Breeding Station. Bull. Ser. H. No. 3. pp. 159-166. 1924.

———— The importance of strain in red clover. *Agric. Progr.* 1. 50-9. 1924.

———— Winter keep. *Welsh J. Agric.* 1. 119-130. 1925.

———— Lucerne growing in high and wet districts. Rothamsted Conferences. No. 1. p. 19. Jan., 1926.

———— Clover problems. *Welsh J. Agric.* 3. 106-18. 1927.

———— Red clover investigations, 1919-1926. Welsh Plant Breeding Station. Bull. Ser. H. No. 7. pp.136. Aberystwyth, 1927.

———— Montgomery and Cornish marl red clover. *J. Minist. Agric.* 34. 133-46. 1927.

———— Comparative agronomic values of red and white clovers of different origin. *J. Dept. Agric. Ireland.* 28. 67-74. 1929.

———— Some of the factors influencing yield and quality of red clover seed. Welsh Plant Breeding Station. Bull. Ser. H. No. 11. pp. 60-91. Aberystwyth, 1930.

———— Self and cross-sterility in red clover. Welsh Plant Breeding Station. Bull. Ser. H. No. 12. pp. 181-208. Aberystwyth, 1931.

———— Self and cross-sterility in white clover. Welsh Plant Breeding Station. Bull. Ser. H. No. 12. pp. 209-16. Aberystwyth, 1931.

———— Fertility of various herbage legumes. Welsh Plant Breeding Station. Bull. Ser. H. No. 12. pp. 221-7. Aberystwyth, 1931.

———— Legumes, breeding of herbage. Baillière's Encyclopædia Sci. Agric. Vol. 1. pp. 639-51. London, 1931.

———— Red clover. Baillière's Encyclopædia Sci. Agric. Vol. 2. pp. 1017-22. London, 1931.

———— Methods and technique of breeding red clover, white clover, and lucerne. Imperial Bureau of Plant Genetics : Herbage Plants. Bull. No. 3. pp. 46-76. Aberystwyth, 1931.

———— Self-fertility in lucerne. Welsh Plant Breeding Station. Bull. Ser. H. No. 12. pp. 217-20. Aberystwyth, 1931.

———— Effect of a nitrogenous manure on white clover and a comparison of the productiveness of four types of white clover under simulated pasture conditions. *Welsh J. Agric.* 8. 163-70. 1932.

————, and EVANS, T. W. Chemical composition of various white clovers and of Italian ryegrass. *Welsh J. Agric.* 8. 151-62. 1932.

———— White clover trials, 1926-1930. *J. Minist. Agric.* 39. 708-18. 1932.

————, and SILOW, Ronald Alfred. Genetics of red clover (*Trifolium pratense* L). Compatibility I. *J. Genet.* 27. 341-62. 1933.

———— Möglichkeiten der Züchtung und Veredlung von Gras- und Kleearten. [The possibilities of breeding and improving grass and clover species.] Rep. Second Int. Grassl. Congr. Berl. pp. 51-66. [English summary, pp. 64-6]. Berlin, 1933.

ENGLAND AND WALES, Ministry of Agriculture and Fisheries and Department of Agriculture for Scotland. Report on County trials of late flowering red clover. [1930-1932]. By R. D. Williams. London, 1934. 33 × 20. pp. 14. [Mimeographed.]

WILLIAMS, Rhys David. Genetics of flower colour in *Trifolium pratense* L. 1. Basic white colour (Factor c). *J. Genet.* 31. 431-50. 1935.

————, and EVANS, Gwilym. The efficiency of spatial isolation in maintaining the purity of red clover. *Welsh J. Agric.* 11. 164-71. 1935.

———— Clovers. *Herefordshire Agric. Quart. J.* 4. 12-7. 1936.

———————— Genetics of red clover and its bearing on practical breeding. Die Genetik des Rotklees und ihre Bedeutung für den praktischen Pflanzenzüchter. Rep. Fourth Inst. Grassl. Congr. Gt. Brit., 1937. Sectional Session 3, pp. 238-51. [German summary, p. 250. Discussion, p. 251]. Aberystwyth, 1937.

———————— Heterosis in red clover. Effect of inbreeding in F_2 and F_3 populations. *Welsh J. Agric.* 13. 172-90. 1937.

———————— The frequency of chlorophyll deficient mutants in red clover. [Abstract.] Rep. Brit. Assoc., 1937. Section K, p. 433. London, 1937.

———————— Observations on the comparative value of white clover varieties. *J. Agric. Soc. Univ. Coll. Wales.* 27. 25-7. 1938.

———————— Genetics of chlorophyll deficiencies in red clover (*Trifolium pratense* L.). 1. Albinos. *J. Genet.* 37. 441-58. 1939.

———————— Genetics of chlorophyll deficiencies in red clover (*Trifolium pratense* L.). 2. Yellow seedling factors. *J. Genet.* 37. 459-82. 1939.

———————— Genetics of cyanogenesis in white clover (*Trifolium repens*). *J. Genet.* 38. 357-65. 1939.

———————— Incompatibility alleles in *Trifolium pratense* L.; their frequency and linkage relationship. *Proc. Seventh Internat. Genet. Congr. Edinb.* 1939. p. 316. Cambridge, 1941.

IRRIGATION OF LUCERNE IN U.S.S.R.*

The water relations of lucerne are of an extremely singular nature. The whole organism is adapted to the acquiring and giving off of large quantities of water. The plant possesses a vigorous root system, well-ramified growth, a large leaf surface**, a long vegetative period, and the ability to give 4–6 hay cuts a year.† The absolute amounts of water given off by lucerne are two to three times larger than in the case of cereals. At the same time, lucerne is able to endure prolonged droughts without dying. "In most desperately dry years in south Russia all the herbage plants, even *Bromus*, withered ; lucerne alone continued to look green" (Klingen, 1909). Such a combination of contrary attributes is apparently the cause of the diverse estimates of the water requirements of lucerne.

There exist two different points of view on this question :

1. A constant high soil humidity and an abundance of warmth and sunshine are the conditions under which lucerne grows best, that is to say, with a favourable system of irrigation in dry regions and in those liable to drought. Lucerne gives increased yields with an increase in the number of individual waterings and in the total irrigating rate. These views have received practical application on the irrigated farms in the U.S.A.

2. Lucerne is capable of enduring drought and absence of waterings for a long time. While all other crops die if waterings are postponed for a protracted period (2-3 months), lucerne always survives these conditions. It is chiefly the lucerne crops which should receive smaller rates of watering when a temporary or permanent shortage of water exists in the irrigated areas. This view is reflected in the proposals for the optional irrigation of lucerne in dry years, recommended for the annual regulation of the available water resources for irrigation purposes in the trans-Volga region, and also in the projected 2-3 months' break in lucerne waterings on irrigated lands of Azerbaïdžan in the second half of the season (Belousov, 1940).

A definite consistency can, however, be observed in all the widely differing estimates of the water consumption of lucerne. The conviction that it is necessary to water lucerne crops regularly prevails in those regions where irrigation has been practised for many years and where a high level of agronomical technique has been attained. For example, Janiševskiĭ (1929) writes : "Give lucerne more waterings." A non-committal attitude is characteristic of those regions where irrigation has been recently introduced and where opinion is still dominated by the traditions of dry farming. Thus, Samsonova (1935) in working out the optimal water régime of the basic crops for the trans-Volga region, concluded : "In contrast to wheat, lucerne appears to be an unexacting

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* Translation by R. Peter Jones, Welsh Plant Breeding Station, of an article in Russian by S. K. Kondrašev of the Moscow Institute of Hydrotechnique and Amelioration in *Vest. seljskohoz. Nauk. Kormodobyvanie*, 1941, No. 2, pp. 78-86.

** According to Verner the area of the surface of the leaves on 1 ha. sown with lucerne amounts to 85 ha.

† In the cotton growing regions of the U.S.S.R.

crop in regard to water ; thus it tolerates fairly well an abundance of moisture on satisfactorily drained soils ; it also endures fairly well dryness both of the soil and of the atmosphere, falling in this case as if it were into a state of dormancy, in order to begin intensive growth anew. When conditions become favourable no plant responds so favourably to additional doses of water as lucerne." But even in this characteristic may be noted the increased productiveness of lucerne under the influence of irrigation.

The nature of the watering régime should be determined in accordance with that peculiarity of the plant. Lucerne is included in the rotation to obtain high yields and to serve as an excellent preceding crop, but not to test its ability to live for several months without irrigation. Therefore the effect of irrigation on yield requires to be ascertained.

Irrigation and Yield.

On non-irrigated soils, the yield of lucerne is reduced as one progresses from north to south and from west to east. This is confirmed by the summarized data of the research stations prepared by Sokolov (1934), extracts from which are given in Table 1.

Table 1.

Area	Experiment Station	Average yield of hay of lucerne over a period of years (ctr. per ha.)*
Forest steppe (west)	Kiev	41
,, ,, (east)	Amur	26
Northern steppe (west)	Taganrog	52
,, ,, (east)	Semipalatinsk ...	26
Southern steppe (west)	Eïsk	25
,, ,, (east)	Krasnokut	17
,, ,, (east)	Temir	8

The largest yields of hay and seed of lucerne are obtained on irrigated lands, and the study of the influence of irrigation is of great practical importance. Owing to the peculiarities of lucerne, however, the use of complex schemes and more accurate methods is necessary. Failure to pay attention to these conditions leads to unconvincing results. In laying down experiments with waterings of lucerne or in utilizing the results of similar observations, the following facts should be taken into account :

1. As lucerne is cultivated on one field for several years, the experiments should remain down throughout the cycle during which lucerne remains in the rotation. Investigation limited to only one watering season and, so much the more, to one hay cut may give incorrect results, as the effect of previous waterings is not then taken into account. For example, a single supplemen-

* To convert ctr. per ha. to lb. per acre, multiply by 89.

tary watering to provide reserves of moisture, given at the Tadzik Station of the Federal Cotton Research Institute, produced an increase in the yield in spite of a reduction in the number of waterings which are usually given during the vegetative period (Sokolov, 1939). Indeterminate results were obtained in 1926 at the Valuïki Station where varying rates of watering were tested for the second cut and identical ones for the remaining cuts (Michaïlov and others, 1934).

2. As lucerne possesses a great capacity to utilize subsoil water, this factor should be entirely eliminated in setting up such experiments. If this is impossible, observations should be confined to the study of the water balance and to the part played in it by the subsoil water as compared with the irrigation water. Failure to take into account such details might lead to incorrect conclusions. For example, at the Valuïki Station in 1928 the following yields were obtained (Kostyčev, 1930): without irrigation, 73 centners per hectare of dry hay; with an irrigating rate of 1,000 m.^{3} per ha., 95 ctr. per ha.; with 1,800 m.^{3} per ha., 98 ctr. per ha.,; with 1,100 m.^{3} per ha., 93 ctr. per ha.,; with 1,500 m.^{3} per ha., 89 ctr. per ha. In 1929 with rates from 3,100 to 5,500 m.^{3} per ha. the yields decreased to 45-56 ctr. per ha., and on the non-irrigated plot to 23 ctr. per ha. This may be explained by the high level of the subsoil water. In 1928, it lay 60 to 100 cm. below the surface and in 1929 it rose to 30 to 40 cm. (Krenitskiĭ, 1938). The rise in the level not only nullified the difference in irrigation, but also influenced the general reduction in yield.

3. Lucerne is highly responsive to manuring. Responsiveness is not fully manifested without irrigation, but irrigation on soil lacking in fertility does not produce the proper effect. On this account, it is essential that experiments with waterings should be conducted on land in a highly fertile condition and should be accompanied by the study of the rates of application of fertilizers.

4. Fertilizers have a protracted after-effect. Under irrigation, the after-effect becomes more pronounced, and lucerne reacts more strongly than other crops. It is, therefore, necessary to conduct experiments with waterings on fields of equal fertility.

In the principal cotton-growing districts, the irrigation of lucerne is a routine obligatory procedure. Therefore, comparison with a control non-irrigated plot, general in grain-producing areas, should not be permitted.

Lucerne should be watered well from the first year. The yields of old stands of lucerne are reduced to a less extent with low irrigating rates than those of young stands which have not developed a deep root system. With good irrigation in the seeding year, lucerne invariably gives an increased yield in the following year if the same watering régime is maintained. There is therefore no reason to adopt reduced rates of irrigation either in the first or subsequent years. Proof of these statements is furnished by experiments conducted at Ak-Kavak during the years 1930-1932 (Table 2). (Starov, 1937).

TABLE 2

Year of sowing	Year of sowing		In the 2nd Year.		Yield of hay for 2 years (total)		Expenditure of water in m.³ per 1 ctr. ha.
	Total irrigating rate in m.³ per ha.	Yield of hay after 3 cuts in ctr. per ha.	Total irrigating rate in m.³ per ha.	Yield of hay after 3 cuts in ctr. per ha.	ctr. per ha.	per cent.	
1930	3,000	13·7	4,000	53·7	67·4	100	104
1930	5,000	22·7	5,000	64·2	86·9	135	115
1931	9,000	73·3	10,000	114·6	187·9	291	101

In most cases it would be self-deception to plead scarcity of water as the reason for giving insufficient amounts to crops. In these instances such a low yield is obtained that the dissipation of insufficient water resources in irrigation channels cannot be vindicated.

The Experiment Station at Brooks (Alberta, Canada) concluded that crops should be watered not only in accordance with expected yield but also with age of stand. It is necessary to water young stands more liberally than older stands (Snelson and Tempest, 1930). With a yield of 25 ctr. per ha. the consumption of water of a 2-year old stand was equivalent to 2,300 m.³ per ha., of a three-year old stand to 2,000 m.³ per ha., and of a 4- to 5-year old stand to 1,800 m.³ per ha. With a yield of hay of 140 ctr. per ha. the corresponding rates of water consumption were equivalent to 9,000, 6,500 and 6,150 m.³ per ha.

The number of waterings during the vegetative period should be approximately twice the number of hay cuts. For grain-producing regions, the ratio may be from one to two, and for cotton-growing regions from two to three. At the Ak-Kavak Station the yield rose continuously with an increase in the number of waterings (Malinkin, 1935). If the yield with one irrigation be regarded as equal to 100 per cent, it amounted with two waterings to 146 per cent and with three waterings to 204 per cent. Similar results were obtained at the Turkmen Experimental Station (Table 3.) (Koldaev and Jazykov, 1939).

TABLE 3.

Scheme of waterings for the season*	Yield of dry hay	
	ctr. per ha.	per cent.
2–1–1–1		
(*a*) Height of water: 10 cm.	96	100
(*b*) ,, ,, ,, 15 cm.	112	116
2–2–2–2		
(*a*) Height of water: 10 cm.	122	127
(*b*) ,, ,, ,, 15 cm.	136	142

NOTE.—Up to the first hay cut two waterings were given. With one watering per cut this was carried out during shooting, and with two cuts, during shooting and in the period of budding.

* " Scheme of waterings for the season " in Table 3 and the other tables means the apportionment and number of waterings for hay cuts of lucerne.

According to observations in 1936 at the Valuïki Station the transition to two waterings per cut considerably increased the yield of hay of lucerne, as shown in Table 4. (Krenitskiĭ, 1938).

TABLE 4.

Number of waterings			Scheme of waterings for the season	Rate* in m.³ per ha.		Yield of hay after 3 cuts		Expenditure of water in m.³ for 1 ton of hay
during the autumn	during the vegetative period	Total		Watering	total irrigating	ctr. per ha.	per cent.	
0	0	0	0–0–0	...	...	24	28	...
0	2	2	0–1–1	1,140	2,290	65	76	352
1	2	3	0–1–1	1,220	3,650	69	80	530
0	3	3	1–1–1	1,190	3,590	86	100	418
1	3	4	1–1–1	1,220	4,890	113	192	433
0	6	6	2–2–2	1,200	7,220	178	208	405

* Watering rates in round figures.

As demonstrated by our computations the relative expenditure of irrigation water per unit of yield was not thereby increased.

The provision of large doses of water at infrequent intervals produces more unsatisfactory results than frequent waterings with small doses. With infrequent waterings, high watering rates must be used, as after long intervals between waterings the soil becomes very dry. With more frequent waterings the total irrigating rate need not be high. This correlation between the number of waterings, their rates, the general irrigating rate and the yield is confirmed by an experiment at the Ak-Kavak Station (Table 5).

TABLE 5.

Waterings during the vegetative period in the year of sowing		Rate m.³ per ha.		Humidity of soil (per cent.)	Yield of hay after 4 cuts		Expenditure of water in m.³ for 1 ton of hay
Number	Scheme of the season	average watering	total irrigating		in ctr. per ha.	in per cent.	
6	1–2–2–1	1,490	8,940	55	73·3	100·0	1,220
8	2–3–2–1	1,210	9,680	65	84·9	115·8	1,140
10	3–3–3–1	997	9,970	75	88·9	121·3	1,120

The advantage of moderate watering rates combined with a large number of waterings was also established at the New Mexico Experiment Station (Skornjakov, 1915). With fortnightly waterings, with watering rates of about 760 m.³ per ha. and a total irrigating rate of 9,930 m.³ per ha., the yield

of hay was 61 ctr. per ha., while with waterings every 28 days (with m=1,515 and M = 9,180 m.³ per ha.)* the yield proved to be less than 53 ctr. per ha.

An increase in frequency of waterings without an alteration in rate of irrigation does not, however, always cause a marked increase in yield. Thus, in experiments conducted in California from 1922-1924 with three waterings, with a total irrigating rate of 9,140 m.³ per ha. and a watering rate of 3,050 m.³ per ha. there was obtained, on the average for 3 years, up to 164 ctr. per ha. of lucerne hay; but with the same irrigating rate and with twelve waterings where $m = 760$ m.³ per ha., the yield rose to 172 ctr. per ha. (Beckett and Huberty, 1928). The slight effect of such marked changes in the number of waterings and in the amount of watering rates is due to the presence of impermeable layers in the soil; with large rates of watering the water did not penetrate beyond the limits of expansion of the root system and was used up gradually by the lucerne. This conclusion is confirmed by the observations of the Rice Research Station in Krasnodar.

Yielding capacity must be the fundamental criterion for the determination of the rate of irrigation. In this respect only a few data are furnished by earlier investigations, as only small and medium rates of watering were tested. Recently in the cotton-growing regions of Central Asia the study of irrigating rates of the order of 8,000 to 10,000 m.³ per ha. has been begun. In the United States of America, higher rates have been tested and have given positive results. Izraeljson (1936) cites investigations which are interesting as regards the steady increase in the yields with a rise in the irrigating rates and also on account of the absolute size of M. In the Salt River Valley in Arizona, the increase in yields continued with a rise in the irrigating rate up to 21,000 m.³ per ha., but a rate of 12,000 m.³ per ha. was likewise considered adequate. Observations over a period of 28 years at the Utah Experiment Station showed that a rapid increase in the yields continued with a rise in the irrigating rate up to 6,200 m.³ per ha.; with a further rise, the yields continued to increase, but less rapidly. Excessive M rates of the order of 25,000 m.³ per ha. did not, however, cause a reduction in the yields of lucerne, as invariably happened with other crops.

In 1934/35, similar data were obtained in South Africa (Bosman, 1936). The precipitation for the vegetative period was approximately 400 mm. In Table 6 the yield of hay of irrigated lucerne is compared with the yield from non-irrigated fields.

TABLE 6.

Number of waterings	Total irrigating rate in m.³ per ha.	Yield in per cent.
0	0	100
6	4,570	280
12	9,140	390
16	12,190	470
22	16,760	500
32	24,390	540

* m=watering rate, that is the quantity of water in cu.m. for one watering. M=irrigating rate, that is the quantity of water in cu. m. for all waterings (taken together).

Yields are favourably influenced in most cases by giving waterings outside the vegetative period in order to provide sufficient reserves of moisture for the stand when vegetative development begins. Such waterings are carried out in the winter-spring period in the basins of those rivers which are fed by glaciers, and in the spring in the case of rivers fed by snow. In one of the experiments at Ak-Kavak (Starov, 1937) with a single reserve watering, the yield of lucerne hay amounted to 103 ctr. per ha. compared with 88 ctr. per ha. with waterings during the vegetative period only (an increase of 15 ctr. per ha. or 17 per cent). Reserve waterings should be given in addition to, but not instead of, waterings during the vegetative period. Waterings in the winter period are contra-indicated where the subsoil water is at a high level.

The statement as to the absence of "critical periods" in the development of lucerne should be accepted with some reservation, that is to say, lucerne tolerates the transposition of waterings during the vegetative period and will not die as a result of lack of water in one of its phases of development. The plan of waterings within the hay period is, however, by no means a matter of indifference where lucerne is concerned. In the case of fodder lucerne, with one watering per cut, this should be given in the budding phase; with two waterings, at the beginning of the shooting and budding phases respectively (Koldaev and Jazykov, 1939). If it is assumed that the scheme of irrigation of lucerne consists of three phases between the cuts (shooting, budding and flowering) the best result was then obtained at Ak-Kavak with the scheme 1–1–0 (Table 7). Lucerne proved most responsive to watering in the budding phase. These observations unfortunately did not include the scheme 1–1–1.

TABLE 7.

Scheme of waterings per cut	Yield of dry hay after 2 cuts		Note
	in ctr. per ha.	in per cent.	
1–0–1	12·7	100	The experiment was conducted in the year of sowing.
0–1–1	16·5	131	
1–1–0	22·7	179	

In the cotton-growing regions, seed crops should be watered 2 to 3 times so as to complete irrigation at the beginning of flowering (Koldaev and Jazykov, 1939). According to observations in 1935 at the Valuĭki Station the best yield of seed was obtained after three waterings according to the scheme 1–1–1 (Krenitskiĭ, 1938).

Fodder stands are mainly irrigated through channels and more rarely by flooding. Seed lucerne is watered along the furrows. Additional investigations are necessary to ascertain the practical value of the suggestion that fodder lucerne should also be irrigated along the furrows.

With lucerne considerable variations exist in the routine irrigation methods employed. In collective experiments in the Golodnaja Steppe, lucerne was given six waterings according to the scheme 1–2–1–2 (Dept. Agric., 1907-15). In the lower reaches of Amu-Darja old stands of lucerne were usually given not less than 8 waterings (Table 8).

TABLE 8.

Particulars about waterings	District			
	Hodžeïli	Šurahan*	Čimbaï	Kunja-Urgenč
Available water resources	Excellent	Good	Medium	Poor
Average watering rate m.³ per ha....	1,129	924	1,024	1,067
Total irrigating rate m.³ per ha. ...	15,810	12,020	11,270	8,540
Number of waterings	14	13	11	8

* Yield of lucerne hay in Šurahan about 200 ctr. per ha.

The following amounts are usually given to fodder lucerne in Central Asia ; 6,235 m.³ per ha. at Isfara ; 5,906 m.³ per ha. in Iski-Taškent ; and 6,004 m.³ per ha. in the Samarkand district. Hačaturjan (1935) cites the characteristic practice for the low-lying zone of Armenia (Table 9).

TABLE 9.

Basins	Periods in days			Number of waterings	Rates m.³ per ha.	
	Irrigating	Average watering	Average interval between waterings		watering	total irrigating
Vedi-čaï	128	31	14	3	700	6,380
Garni-čaï	134	25	25	6 to 7	810	5,050
Abaran-čaï	134	22	26	7	850	6,000
Araks	159	37	9	5	680	10,500
Zangi	145	29	13	12	1,400	16,800

Three waterings were given during the season to the commercial crops of lucerne at the Valuïki Station between 1923 and 1926. The following average rates were given during the first, second and third waterings respectively : 1,337 1,431, and 1,550 m.³ per ha. In the individual years the rates varied from 1,000 to 1,800 m.³ per ha. On the average for the years 1923-1926, the total irrigating rate was equivalent to 4,318 m.³ per ha.

Four waterings, with a general rate fluctuating from 3,800 to 4,770 m.³ per ha., were given to crops on the Sunženy plot in 1928; the yield varied from 95 to 100 ctr. per ha. (North Caucasia, 1928). A watering of 1,200 m.³ per ha. after each cut was given to crops on the Kizljar plot in 1927 ; the total hay harvested after 4 cuts was 106 ctr. per ha. (Karolev, 1933). Alexandrov (1916-18) fixes the irrigating rate for lucerne in the Taškent region at 8,000 to 9,000 m.³ per ha. to be given in six waterings during the vegetative period.

Ponjakovskiï (1933) states that in the cotton-growing regions of Central Asia, lucerne crops should be given eight to ten waterings during the vegetative period with an irrigating rate of the order of 6,000 to 8,500 m³. per ha. With

proper care a yield of 100 to 200 ctr. of dry harvested mass per ha. may be obtained. "In point of fact it is given not more than 6 waterings with an expenditure of water of from 4,500 to 6,000 m.³ per ha., that is, about half the optimum amount. The low yields are therefore not to be wondered at."

This statement is not only proof of the inadequate attention which is paid to the irrigation of lucerne. Šleĭher (1934), when describing the agronomical technique of the cultivation of lucerne, states that a single watering is given to crops of lucerne after each cut in the Zeravšany valley. Stands of lucerne on lands with highly permeable soils, where the subsoil water is at a deep level, form the only exception and they receive two waterings between the first and second cuts ; but such an exception does not alter the general picture.

Lucerne is watered heavily in the U.S.A., receiving there considerable amounts unprecedented even in the cotton-growing zones of the U.S.S.R. not to mention the grain-producing areas of our country. An investigation by the U.S. Department of Agriculture showed that irrigating rates generally employed varied from 7,600 to 13,100 m.³ per ha., reaching in individual cases 18,000 to 47,000 m.³ per ha. (Skornjakov, 1915).

The number of waterings varies from four in the north (Montana) to twelve in the south (Arizona, California). On many stands in the western states (Forteir, 1917), the irrigating rate varies from 7,500 to 13,500 m.³ per ha., but frequently more modest rates are employed : from 1,000 to 4,500 m.³ per ha. (Piper, 1930). In the estimation of these rates it should be borne in mind that irrigation is complementary to natural precipitation, which is considerable in the principal zones of lucerne cultivation in the U.S.A. It is interesting to record the growth in the U.S.A. of the practice of frequent waterings of lucerne on light, permeable soils. On the light sandy soils at the Umatilla Station, Utah, the best yields are obtained with two waterings a week. On the poor soils in the same State, waterings are carried out in summer every 10 days (Israeljson, 1936).

The northern part of the U.S.A., in particular the State of Montana, may be considered similar in climate to the trans-Volga region. There are usually only two normal hay cuts and one half of the annual precipitation falls in the period April-June. The yield obtained on heavy soils is about 93 ctr. per ha. with an irrigating rate of 5,850 m.³ per ha., and on light soils 105 ctr. per ha. with an irrigating rate of 6,550 m.³ per ha, (Forteir, 1917).

Mirkin (1935) analysed extensive material on the subject of the irrigation of lucerne in Canada and the U.S.A., and gave a comprehensive table from which could be gathered the significance of absolute figures illustrating the water consumption of lucerne, the yields, and also of the figures expressing the coefficient of water consumption, as shown in the formula :

$$\frac{\text{precipitation} + \text{irrigating rate}}{\text{yield of dry hay}}$$

The mean coefficients of water consumption fluctuated within fairly wide limits : from 600 to 1,200, but those occurring most frequently are confined to the range from 600 to 800. With manuring the coefficient of water con-

sumption falls. The penetration of water into the soil on lucerne plots must be deep, not less than 1 metre. With a rise in the level of the subsoil water to 1.5—1 m. the need for irrigation is reduced, but at the same time the yield also decreases. Other herbage plants utilize water less efficiently than lucerne.

The National Commissariat of Agriculture of the U.S.S.R., the Commissariats of Agriculture of each of the Federal Republics and Provincial Departments of Agriculture publish annually their instructions concerning the rates of watering of lucerne in all those territories with considerable areas of lucerne under irrigation. It is stated, for example, in the instructions regarding lucerne issued by the Commissariat of Agriculture of the U.S.S.R., 1940, p. 10, that "irrigation plays a decisive role in increasing the yields of lucerne, and for this reason special attention should be paid to regular and proper watering." In Table 10 we give, as an illustration of the above, the scheme of normal rates of watering during each phase of the vegetative period in the cotton and cereal-growing districts.

These schemes are, of course, altered according to local conditions. To provide reserves of moisture, for example, on those lands where during the autumn-winter period the subsoil water is at a deep level, additional waterings require to be given to crops growing on highly permeable soils ; the number of normal waterings should also be increased ; but on lands where the subsoil water is at a shallow level it should be reduced. The scheme as cited was devised with a view to obtaining high yields of fodder and seed of lucerne. Some of the suggestions for reduction of rates of watering were not included because they require further study.

Among such proposals should be noted those put forward by the Azerbaïdžan Cotton Research Institute for introducing into the rotations lucerne which was not given "full rates of watering," that is, lucerne which does not receive waterings during the second half of the summer. This proposal was made on the basis of experiments carried out from 1932-1935 when the effect of intervals of 2 and 3 months between waterings was tested. In these experiments there was observed a reduction of 15 to 17 per cent in yield as compared with "normally"* watered lucerne , but if the interval was preceded by a month of increased waterings, the yield was reduced by only 6 per cent (Belousov, 1940). This evidence, however, contradicts the data obtained by other research institutes. Thus, according to the observations of the Institute of Plant Breeding in Central Asia from 1930 to 1933, a mass shedding of leaves was observed in 15 to 40 per cent of lucerne plants which remained in a state of wilting (pronounced but not altogether fatal) for a period of 6 to 11 days.

On plots where the subsoil water is at a shallow level, lucerne may more easily tolerate interruptions in irrigation. (Dvoričenko, 1925) states that on the Malek plantation (the Golodnaja Steppe) one field of lucerne sown in 1918 was abandoned in 1919 ; it was neither watered nor manured and was not cut until 1923, and yet all the lucerne survived. According to Prjanišnikov

* Inverted commas appear in the original accompanied by the explanation that by normal watering is meant one watering per cut. One watering per cut is certainly insufficient. —Author's footnote.

and Jakuškin (1938), this case may be referred to the fourth type of lucerne cultivation, the necessary water being obtained principally from the subsoil water ; this type is not characteristic of irrigated lands.

There has undoubtedly been a considerable improvement in the last decade in the quality of the scientific data on the basis of which the plans for the irrigation of lucerne were prepared. Prior to the promulgation of a decree by the Party and the Government on the introduction of crop rotations into the system of agriculture, attention was in the main devoted to the leading crop when plans were prepared in regions where water was available for irrigation. Not only was very little attention paid to the lucerne crops, but the water which was intended for them was regarded as a general reserve to be drawn upon when the necessity arose to provide full watering rates for the leading crop according to the accepted scheme of irrigation. Such a practice resulted in the first place in a reduction in rates of watering, and in the second place led to a decrease in the number of waterings. This is illustrated by the details as given in the 1930 plans prepared for the Zeravšany Valley (Taškent, 1930).

When, however, the estimates were based on the actual modifications of waterings suitable for a particular crop in a particular locality, there was not provided at the same time a full analysis which would show the relation of that modified plan of irrigation to the planned figures of the yields in that particular locality. It was apparently supposed that the increase in the yield of lucerne would result from measures other than the modification of the watering régime. This is what actually happened in the 1930 plans prepared for the Čirčik-Angrena basin (Moscow, 1930).

Such an attitude to the technique of irrigation of lucerne may be explained by the fact that at the time the plans were prepared the view was generally held that mono-culture of cotton is not only feasible but also necessary. For this reason, the low watering rates allocated to lucerne crops in these plans were really the reflexion of the projected cultivation of cotton as a single productive crop.

Conclusions.

1. Lucerne is considered to be the best preceding crop in all specialized crop rotations on irrigated soils—wheat, cotton, rice, etc. The rates of irrigation of lucerne are, however, not always commensurate with the importance of this crop. When schemes of irrigation are prepared, most attention is paid to the crop of greatest importance in the rotation.

2. Lucerne is the first crop that does not receive its due share when there is an insufficiency of water. Its capacity to endure insufficient irrigation has served as the justification for a reduction in the number of waterings and for the proposals concerning the discontinuance of watering in the second half of the summer, or even for its total omission in years when water is in short supply.

3. Under the influence of deficient waterings lucerne not only gives a reduced yield but fails to vindicate itself in its role of the best preceding crop.

Moreover, where the predominating crops receive full irrigation rates, but at the expense of lucerne, their yields are also reduced.

4. The efficiency of a regular rotation is impaired by insufficient attention to the irrigation of lucerne in general and by inadequate rates of watering in particular; this attitude is the reflexion of the prevailing views on the necessity of concentrating on cultivation of single productive crops.

5. The instructions relating to the cultivation and irrigation of lucerne as worked out by the government departments ensure normal development and high yields (100 to 120 ctr. of dry hay per ha. in the grain-producing regions and 140 to 180 ctr. per ha. in the cotton-growing districts) provided they are meticulously carried out.

TABLE 10.

Method of utilization of crop	Republic or province	Age of lucerne	
		Seeding year	Old stands
1	2	3	4
Fodder ...	Saratov ...	(*a*) Cultivation with cover crop (summer cereal). Up to harvesting of cover crop the lucerne is watered at the same time as the cover crop. After harvesting of the cover crop the young lucerne receives 1 or 2 waterings according to the plan per cut : 0-1-0 or 1-1-0	(*a*) Northern zone, 3 waterings with total quantity of water = 3,000-3,600 m.^{3} 1st in 30 days after the beginning of shooting, 2nd immediately after the first cut, 3rd immediately after 2nd cut.
		(*b*) Cultivation without cover crop. Up to the 1st cut the lucerne receives 2-3 waterings, the first watering being carried out on the appearance of the 3rd ternate leaflet. The 2nd cut is watered according to the plan 1–1–0.	(*b*) Central and southern zones, 5 waterings with total quantity of water=4,500-5,000 m.^{3} 1st in 30 days after beginning of shooting, 2nd after the 1st cut, 3rd in the budding phase of the 2nd cut, 4th after the 2nd cut, 5th in the budding phase of the 3rd cut.
	Central Asia, Southern Kazahstan.	(*a*) Cultivation with cover crop (spring or winter cereal). After harvesting of cover crop lucerne receives 2-3 waterings per cut according to the plan 1–1–0 or or 1–1–1.	(*a*) Northern zone, 2 waterings per cut according to the plan 1–1–0.
		(*b*) Without a cover crop, up to the 1st cut 3-4 waterings, subsequently 2 waterings per cut.	(*b*) Central zone, 2-3 waterings per cut according to the plan 1–1–0 or 1–1–1. (*c*) Southern zone, 3 waterings per cut according to the plan 1–1–1. Watering rates 800-1,200 m.^{3}

Method of utilization of crop.	Republic or province.	Age of lucerne.	
		Seeding year.	Old stands.
1	2	3	4
	Azerbaĭdžan.	Up to the 1st cut 3 waterings, subsequently 2 waterings per cut.	(*a*) In regions with an adequate provision of water 2 waterings per cut according to the plan 1–1–0 with rates of 800-900 m.³
			(*b*) In regions with a small supply of water up to June inclusive 2 waterings per cut are given with rates of 1,000-1,100 m.³, subsequently 1 watering.
Seed production.	Central Asia, Southern Kazahstan.	From sowing to harvesting for seed 3 to 6 waterings are given according to the plans from 1–1–1 to 3–2–1.	1 to 3 waterings for each cut for seed, the last watering being given not later than the beginning of flowering.
	Azerbaĭdžan.	From sowing to harvesting 3 waterings are given.	(*a*) With water-tables at a deep level 3 waterings : 1–1–1.
			(*b*) With shallow water-tables 1 to 2 waterings.

Note—Rates of watering indicated in m³ per ha.

References.

Alexandrov, N. N. 1916-18. Agriculture in the Syr-Darja Province. Description of farming methods mainly on the cotton and dry farms in the Taškent district. *Turk. Selsk. Hoz.* Taškent. pp. 256.

Baku. 1940. Instructions on the agrotechnique of fodder and seed lucerne in irrigated cotton growing districts of Azerb. S.S.R. for 1940. pp.20.

Beckett, S. H. and Huberty, M. R. 1928. Irrigation investigations with field crops at Davis and Delhi, California, 1909-1925 (Berkeley Univ., Calif. Exp. Sta. Bull. 450).

Belousov, A. S. 1940. Agrotechnical principles to be considered in planning cotton rotations in Azerbaĭdžan. Baku. pp. 64.

Bosman, F. H. 1936. Water in relation to plant growth. Fmg. S. Afr. Vol. 11. No. 123.

Delinikaĭtis, S. A. 1935. Agriculture under irrigation. Saratov. pp. 216.

Department of Agric. of the Central Board of Agric. and Land Settlement in St. Petersburg. Reports on the activities of experimental cotton stations in Turkestan and in Transcaspian Province. Parts I-VII (for the period 1906-12) were published between 1907-1915.

Dvorničenko, M. P. 1925. The Malek lucerne stands. *Klopk. Delo.* No. 3-4. pp. 261-266.

Fortier, S. 1917. Irrigation of alfalfa. (U.S. Dept. Agric. Fmrs.' Bull. 865, Washington, D.C.)

Golovčenko, S. G. 1940. New method of cultivation of fodder lucerne. *Soc. Zern. Hoz. Uzbekistan.* No. 2. pp. 17-19.

Hačaturjan, S. A. 1935. Water resources in the low lying zones of Armenian S.S.R. Tiflis, pp. 174. Map. No. 10.

Izraeljson, O. 1936. Scientific bases of the practice of irrigation. English translation edited by N. A. Maximov. pp.334.

Janiševskiĭ, N. A. 1929. Ten commandments of utilization of water. Taškent. pp.15.

KIRIČENKO, K. S. 1940. The water régime of the soil in rice field rotations. [Manuscript from the Rice Station, Krasnodar.]
KLINGEN, I. 1909. Forage plants and their usefulness. 2nd ed. St. Petersburg. Part 3, Legumes. pp. 132.
KOLDAEV, A. A. and JAZYKOV, P. P. 1939. Agrotechnique of fodder and seed lucerne. Taškent. pp. 88.
KONDRAŠEV, S. K. 1916. Irrigated farming and the utilization of water in the Hiva oasis. Moscow. pp. XII + 344.
KOROLEV, B. I. 1933. Results of the work of Kizljar Experimental Ameliorating Station for 1925-30. Mahač-Kala. pp. 113.
KOSTYČEV AGRICULTURAL AND MELIORATIVE EXPERIMENTAL STATION AT VALUIKI. 1930. Short report on the present state, work and future activities for the period 1894-1929. Pokrovsk. pp. 185.
KRENITSKIĬ, P. R. 1938. The irrigation régime of lucerne. *Soc. Zern. Hoz.* No. 5. pp. 61-82.
LENINGRAD, WORKS ON APPLIED BOTANY. 1935. The physiological appraisal of irrigation schemes (cotton, wheat, lucerne, roots and oil plants). Results of work of Feder. Plant Breed. Inst. in Central Asia during 1930-33. Ser. No. 14. pp. 258.
MALINKIN, N. P. 1935. Intensification of young lucerne. *Borjba za Klopok.* No. 5-6. pp. 75-84.
MIHAĬLOV, M. N., SOKOLOV, A. A., LEVITAN, JU. M., and BEK, F. S. 1934. Farm crops and their cultivation under irrigation in Trans-Volga. Moscow, pp. 179.
MIRKIN, S. L. 1935. Water requirements of lucerne in N. America. (Manuscript, Chair of Agriculture). Moscow Inst. Hydrotechn. Amelioration.
MOSCOW, COUN. AGRIC. U.S.S.R. 1940. Instructions on the agrotechnique and control of pests and diseases of lucerne in irrigated cotton growing districts for 1940. pp. 23.
Moscow (unpublished material of the State Institute of Water Research, 1930). A scheme for reconstruction of water economy in the Čirčik-Angrena Basin.
NORTH CAUCASIAN REGIONAL EXPERIMENTAL AMELIORATING STATION. 1928. Results of experimental ameliorative investigations for 1928. Part 33. pp. III + 255.
PIPER, C. 1930. Perennial fodder plants and their cultivation. pp.340. [Trans. of English Ed.]
PONJAKOVSKIĬ, S. 1933. The agrotechnique of lucerne. *Borjba za Klopok.* No. 2-3. pp.139-148.
PRJANIŠNIKOV, D. N. and JAKUŠKIN, I. V. 1938. Plants cultivated in the fields. [Special Field Husbandry], 10th ed. Moscow. pp. 759.
SAMSONOVA, N. P. 1935. The optimal water régime for basic crops in Trans-Volga rotations and some data on dry farming. Manuscript, Chair of Agriculture, Moscow Inst. Hydrotech. Amelioration.
SARATOV. 1940. Measures approved by the 2nd conference of leading farmers in the Saratov Province to ensure high yields in 1940. pp. 88.
SKORNJAKOV, E. E. 1915. Cultivation of lucerne under artificial irrigation in N. America. Petrograd. pp. 69.
ŠLEĬHER, A. I. 1934. Agrotechnique of lucerne in the Zaravšany Valley. *Borjba za Klopok.* No. 1-2. pp. 60.
SNELSON and TEMPEST. 1930. Irrigation practice and water requirements for crops in Alberta. Bull. 7. Irrig. Series, Dept. Interior, Canada.
SOKOLOV, A. A., OVČINNIKOV, B. F. and MAKAS, M. F. 1934. Lucerne. Moscow. pp. 172.
SOKOLOV, A. F. 1939. The agrotechnique of lucerne. *Social. Hoz. Uzbekistan.* No. 3-4. pp. 64-71.
STAROV, P. V. 1937. Waterings of lucerne. Taškent. pp. 28.
———— 1937. The rôle of waterings in the intensification of cultivation of lucerne. *Borjba za Klopok.* No. 3. pp. 35-44.
TAŠKENT. 1930. A scheme for reconstruction of water economy in the Zaravšany Valley. (Unpublished material.)

FODDER TREES IN MADRAS

A method by which farmers in the Presidency could obviate the acute problem of providing fodder for cattle in times of drought or famine is that of growing trees which yield fodder. (*See* "Some common fodder-yielding trees in the Madras Presidency" by S. N. Chandrasekhara Iyyar and T. Venkataramaca Reddy in *Indian Forester*, Vol. 68, pp. 435-46 and 536-45, 1942). There are many trees in the area the fodder value of which is not generally known, although some are planted for ornamental purposes. In the following table is recorded a number of trees (not exhaustive) which are fairly quick-growing, drought-resistant, and produce ample foliage. By their cultivation, lands may be utilized which otherwise would lie waste, and additional sources of fodder may thus become available.

Species.	Parts utilized and stock type.	Distribution.	Propagation. Suitable areas.
Acacia arabica.	Ripe pods, leaves and tender shoots. Sheep and goats.	Circars, Deccan and Carnatic. Dry localities, black cotton soils.	Seeds. Pasture and waste lands.
Acacia catechu.	Leaves. Sheep and goats.	N. Circars in Ganjam.	Seeds. Pasture and waste lands.
Acacia leucophloea.	Pods, leaves, tender shoots. Sheep, goats.	Circars, Deccan and Carnatic. Dry localities and deciduous forests.	Seeds. Pasture and waste lands.
Adina cordifolia.	Leaves. Cattle, sheep, goats.	Dry, deciduous forests throughout Madras.	Seeds. Avenues and waste places.
Aegle marmelos.	Young shoots and leaves. Cattle, sheep, goats.	N. Circars, Deccan, and Carnatic. Dry forests.	Seeds. Gardens and waste places.
Ailanthus excelsa.	Foliage. Cattle, sheep, goats.	N. Circars, forests of Ganjam and Vizagapatam.	Seeds. Avenues.
Albizzia amara.	Leaves. Cattle, sheep, goats. Wild cattle on young leafy shoots.	N. Circars, Vizagapatam, Godavari.	Seeds. Avenues and waste places.
Albizzia lebbeck.	Foliage. Cattle, sheep, goats.	All plains districts in Presidency.	Seeds. Avenues.
Albizzia marginata.	Leaves. Cattle, sheep, goats.	N. Circars, Deccan, in hill forests.	Seeds. Avenues.

Species.	Parts utilized and stock type.	Distribution.	Propagation. Suitable areas.
Albizzia odoratissima.	Leaves. Cattle, sheep, goats.	All forest districts in Presidency, and in hills up to 3,000 feet.	Seeds. Avenues.
Albizzia procera.	Foliage. Cattle, sheep, goats.	N. Circars, Deccan in forests; W. Ghats in deciduous forests.	Seeds. Avenues.
Anogeissus latifolia.	Leaves. Cattle, sheep, goats.	Dry, deciduous forests of Presidency up to 4,000 feet.	Seeds. Waste areas.
Artocarpus integrifolia.	Foliage. Cattle, sheep, goats.	W. Ghats, evergreen forests. 1,500-4,000 ft.	Seeds. Avenue, shade and fruit tree.
Azadirachta indica.	Leaves. Sheep, goats and (in some districts) cattle.	Deccan and Carnatic dry forests.	Seeds. Avenue and shade tree.
Balanites Roxburghii.	Leaves. Cattle, sheep, goats.	N. Circars, Vizagapatam, Deccan, Mysore, dry forests.	Seeds. Waste areas.
Bambusa arundinacea.	Leaves. Cattle.	Madras. All districts from 100 to 4,000 feet.	Seeds and clumps.
Bauhinia malabarica.	Leaves. Sheep, goats. Less extent by cattle.	Circars forests, W. Ghats.	Seeds. Avenues and waste places.
Bauhinia purpurea.	Leaves. Cattle, sheep, goats.	N. Circars, Deccan and Carnatic in deciduous forests, water courses, W. Coast, dry forests.	Seeds. Gardens.
Bauhinia variegata.	Leaves. Cattle, sheep, goats.	N. Circars, Deccan and Carnatic, in dry deciduous forests.	Seeds. Gardens.
Bassia latifolia.	Leaves, flowers, fruits. Cattle, sheep, goats.	All deciduous forests of Presidency.	Seeds. Avenues and gardens.
Bombax malabaricum.	Leaves. Cattle, sheep, goats. Seeds also for cattle.	All forest districts.	Seeds. Avenues and gardens.
Buchanania angustifolia.	Leaves. Cattle.	All dry forests of Presidency.	Seeds. Avenues and gardens.

Species.	Parts utilized and stock type.	Distribution.	Propagation. Suitable areas.
Buchanania Lanzan.	Leaves. Cattle, sheep, goats.	All deciduous forests up to 4,000 feet.	Seeds. Avenues and gardens.
Butea frondosa.	Foliage. Cattle, sheep, goats.	All districts, open country and deciduous forests. Common on Black cotton soils and salt lands.	Seeds. Avenues and waste places. Tank bunds.
Cassia fistula.	Leaves. Cattle, sheep, goats.	Deciduous forests, all districts.	Seeds. Avenues and gardens.
Cassia siamea.	Leaves. Cattle, sheep, goats.	Carnatic, common in forests.	Seeds. Avenues and gardens.
Cedrela Toona.	Young shoots, leaves, seeds. Cattle, sheep, goats.	E. and W. Ghats Hills of Deccan.	Seeds. Avenues and gardens.
Cordia obliqua.	Leaves. Cattle, sheep, goats.	Deciduous forests.	Seeds. Avenues and gardens.
Dalbergia latifolia.	Leaves. Cattle, sheep, goats.	Forests of N. Circars, Deccan and W. Ghats.	Seeds. Gardens and waste places.
Dalbergia Sissoides.	Leaves. Cattle, sheep, goats.	W. Ghats. Hills of Travancore to 5,000 feet.	Seeds. Gardens and waste places.
Dalbergia Sissoo.	Leaves. Cattle, sheep, goats.	River beds in sub-Himalayan tract of N. India.	Seeds. Gardens and waste places.
Dolichandrone falcata.	Not stated.	N. Circars, Vizagapatam, Deccan, Carnatic.	Seeds. Waste places
Elaeodendron glaucum.	Leaves. Cattle, sheep, goats.	Deciduous forests.	Seeds. Avenue and shade tree.
Enterolobium saman.	Foliage. Cattle, sheep, goats.	Heavy rainfall areas.	Seeds. Avenue tree.
Eriodendron pentandrum.	Leaves. Cattle, sheep, goats. Seeds also for cattle.	West coast and S. India (naturalized).	Seeds. Gardens and waste places.
Erythrina indica.	Leaves. Cattle, sheep, goats.	Throughout Presidency.	Seeds and stumps. Avenues and gardens.

Species.	Parts utilized and stock type.	Distribution.	Propagation. Suitable areas.
Feronia elephantum.	Leaves. Sheep, goats.	N. Circars, Deccan and Carnatic, dry, open forests.	Seeds. Gardens.
Ficus Bengalensis.	Foliage, fruits. Cattle, sheep, goats.	All districts up to 4,000 feet.	Seeds, stumps. Avenue and shade tree.
Ficus glomerata.	Leaves. Cattle, sheep, goats.	All districts up to 6,000 feet.	Seeds, stumps. Avenue and shade tree.
Ficus infectoria.	Leaves. Cattle, sheep, goats.	All districts up to 7,000 feet.	Seeds, stumps. Avenue and shade tree.
Ficus religiosa.	Foliage. Cattle, sheep, goats.	Widely planted on village sites.	Seeds, stumps. Avenue and shade tree.
Ficus retusa.	Leaves. Cattle, sheep, goats.	All districts up to 4,000 feet.	Seeds, stumps. Avenue and shade tree.
Ficus Tsiela.	Foliage. Cattle, sheep, goats.	Southwards from Kurnool. Forests, from 1,000 to 3,500 feet.	Seeds, stumps. Avenue and shade tree.
Gmelina arborea.	Fruits, leaves. Cattle, sheep, goats.	Deciduous forests up to 5,000 feet.	Seeds. Avenues and gardens.
Guazuma tomentosa.	Leaves. Cattle, sheep, goats.	Wild. Introduced.	Seeds. Avenues, gardens, hedges.
Hardwickia binata.	Leaves. Cattle, sheep, goats.	Deccan and Carnatic, Mysore, Coimbatore and Salem.	Seeds. Waste places and tank bunds.
Holoptelea integrifolia.	Leaves, young pods. Cattle, sheep, goats.	N. Circars in deciduous forests, hills of Deccan, W. Ghats low levels of Travancore.	Seeds. Avenues and waste places.
Kydia calycina.	Leaves. Cattle, sheep, goats.	N. Circars and Deccan. Deciduous forests.	Seeds. Waste places.
Lagerstroemia Flos-Reginæ.	Leaves. Cattle, sheep, goats.	Hills of N. Circars. W. Ghats.	Seeds. Avenues and ornamental tree.
Mangifera indica.	Leaves. Cattle, sheep, goats.	Hill forests of E. Ghats, Deccan and W. Ghats up to 4,000 feet.	Seeds and grafts. Avenue, shade and fruit tree.

Species.	Parts utilized and stock type.	Distribution.	Propagation. Suitable areas.
Morinda tinctoria.	Leaves. Sheep and goats.	South Deccan. Carnatic dry forests.	Seeds. Waste places.
Moringa oleifera.	Tender shoots + leaves. Cattle, sheep, goats.	N. Circars.	Seeds and stumps. Gardens.
Odina Wodier.	Leaves. Cattle, sheep, goats.	Deciduous forests of most districts.	Seeds. Avenues, gardens.
Ougeinia dalbergioides.	Leaves. Cattle, sheep, goats.	Forests of Ganjam, Vizagapatam, Godavari, Mysore.	Seeds. Avenues and gardens.
Pithecolobium dulce.	Pods by cattle, foliage by goats.	All plains districts.	Seeds. Avenues, fences, waste places.
Pongamia glabra.	Foliage. Cattle and goats.	Coast forests and river banks in most districts.	Seeds. Avenues, shade tree. Leaves for green manure. Waste places.
Prosopis julifera.	Leaves, shoots, pods. Cattle.	Arid soils.	Seeds. Pastures and waste places.
Prosopis spicigera.	Pods, leaves. Cattle, sheep, goats.	Deccan and Carnatic, dry stony lands.	Seeds. Pastures and waste places.
Pterocarpus marsupium.	Leaves. Cattle, sheep, goats.	Deciduous forests up to 4,500 feet.	Seeds. Gardens and avenues.
Pterocarpus santalinus.	Leaves. Cattle, sheep, goats.	Deccan.	Seeds. Gardens, avenues and waste places.
Schleichera trijuga.	Leaves and pods. Cattle, sheep, goats.	Forest districts up to 3,000 feet.	Seeds. Avenues and gardens.
Sesbania aegyptiaca.	Leaves. Cattle, sheep, goats.	Wild in plains districts. Also cultivated.	Seeds.
Sesbania grandiflora.	Leaves, flowers, green pods. Cattle.	Cultivated in gardens.	Seeds. Windbreaks in sugar cane fields.
Syzygium Jambolanum.	Leaves. Cattle, sheep, goats.	All forests, plains and up to 6,000 feet.	Seeds. Avenue, shade and fruit tree.
Stereospermum suaveolens.	Leaves. Cattle, sheep, goats.	N. Circars, Deccan, W. Ghats in deciduous forests. Hills of Mysore, Malabar and Travancore.	Seeds. Avenues and waste places.

Species.	Parts utilized and stock type.	Distribution.	Propagation. Suitable areas.
Streblus asper.	Leaves, Cattle, sheep, goats.	All districts up to 2,000 feet.	Seeds. Avenues and waste places.
Terminalia bellerica.	Leaves. Cattle, sheep, goats.	Deciduous forests up to 3,000 feet.	Seeds. Waste places.
Thespesia populnea.	Leaves. Cattle, sheep, goats.	Throughout Presidency.	Seeds, stumps. Avenue and shade tree.
Trewia nudiflora.	Leaves. Cattle, sheep, goats.	N. Circars in hills up to 3,000 feet in wet places among streams.	Seeds. Avenues.
Wrightia tinctoria.	Leaves. Cattle, sheep, goats.	All deciduous forest districts especially Deccan. In W. Ghats up to 4,000 feet.	Seeds. Avenues, gardens, waste places.
Ziziphus jujuba.	Leaves. Sheep and goats.	Deciduous, dry forests. Cultivated near villages.	Seeds and grafts. Waste places.

—M. HALL.

OIL OF TRIFOLIUM SUBTERRANEUM

A note on the oil of the Midseason variety of this clover is published by A. M. McArthur in *Proc. Roy. Soc., Victoria,* Vol. 54 (n.s.) pp. 243-4. 1942. The oil was extracted with ether in a Soxhlet extractor from the finely ground seed and, after removal of the ether, it was dried by heating in a boiling water bath, CO_2 being passed through the flask to prevent oxidation. The amount of oil obtained was 16·8 per cent of the whole seed.

Data from the chemical tests carried out are recorded below :

	Pressed	Extracted
Saponification value...	201	211
Reichert-Meissl No.	1.6	1
Polenske No.	0.7	0.8
Iodine value	108	111
Refractive index at 19.1°C.	1.4680	1.4703
Unsaponifiable matter	1.97%	—

The oil was found to contain about 60 per cent of unsaturated acids and very few acids, either saturated or unsaturated, below C_{10}. Its iodine value is considerably below that of linseed and other oils used for paint manufacture, but since drying properties of oils are not wholly dependent on the iodine value, it is considered that this point may be worth further investigation.

The following table shows that the oil is similar in character to olive, maize and cottonseed oil :

	Saponification value	Iodine value	Unsaturated acids : Percentages
Olive Oil	190.5	85	85
Maize Oil	189.93	115.25	90
Cottonseed oil	191.5	108.16	75
Clover seed oil	201.11	108.11	61

Tests for the presence of vitamin A were done on the unsaponifiable matter of the oil by the Carr-Price test (antimony trichloride in chloroform), and results were negative.—M. Hall.

HERBAGE IN THE CONTROL OF EROSION

Erosion due to heavy and often torrential rainfall is the chief cause of deterioration in the coffee plantations of the State of São Paulo, Brazil. The planters of the region have adopted a variety of measures in their attempts to control it, and an interesting account of these is given by H. V. de Camargo Bittencourt, of the State Division for the Control of Erosion, in the *Boletim da Superintendência dos Serviços do Café*, 18. 230-7, and 322-30, 1943.

In a brief review of the regions in which decadent plantations are located, it is shown that productivity is closely correlated to the resistance to erosion of the soil concerned. In the red earths, for example, productivity is maintained for a very long time, and plantations over 60 years old are still producing profitable crops.

Methods of Control

Coffee trees are planted in straight lines, the holes in which the trees are planted being arranged rectangularly. Generally a culture is laid out in large plots having approximately 5,000 trees, separated from one another by long, straight paths running at right angles to the slope. When it was found that paths and roads located to follow the greatest slope were being gullied by rainfall, efforts were made to dam the run-off. The earliest reference in the literature is an article by Dafert, 1893*, who—as early as that year—recom-

* Dafert, F. W. Sobre a fortificação do solo nos cafezais. [On the conservation of the soil of the coffee plantations.] *Relat. Inst. Agron.* 1893. p. 202.

mended the construction of contour curves with the trunks of trees and earth. The methods of control that have been adopted by planters in the meantime are as follows.

1. *Herbage.* Herbage has been managed in different ways, namely, (*a*) cutting and collecting the crops in ridges running approximately across the slope of the land, between the rows of coffee trees ; (*b*) deferring cutting until the grasses are fully grown, when the mown crop is strewn over the whole surface of the ground ; (*c*) keeping the herbage cut short and preventing it from seeding, the ground remaining undisturbed ; (*d*) cutting in alternate rows, as far as possible, across the slope, so that the cut is taken from one-half of the area, while the herbage of the second half forms retention strips. It is considered that while (*a*) is to a certain degree useful in obstructing the run-off from heavy rainfall, it has the disadvantage of exposing large areas of land, bare and scraped, to the direct action of sun and rainfall. System (*b*) is fairly successful where the growth of the herbage is luxuriant and where the nature and slope of the land favour the control of erosion : of the four systems described, it is perhaps the one most commonly used by the more progressive planters. System (*c*), while employed by some, entails much labour and also a competition between the herbage and the coffee plants, principally for water and especially in the dry seasons. System (*d*) has produced very good results in some especially hilly lands, but it has been little used as yet. It is considered worthy of careful experimental work. Although all these measures tend to lose their efficacy under extremely adverse circumstances, some of them can give satisfactory results under suitable local conditions.

2. *Legumes.* Intercropping with green manure plants has also been employed. The plants used for this purpose are *Canavalia ensiformis, Stizolobium deeringianum,* and sometimes *Crotalaria juncea.* It is considered difficult to determine their direct effect in protecting the soil from erosion. It is true that the organic matter with which they furnish the soil increases its water-absorption capacity and decreases its erodibility, and the plants themselves impede run-off and help to fix the soil, but as they have to be sown at the beginning of the rainy season if they are to compete with weeds and herbage, and as rainfall at this time is apt to be intense and frequent, insufficient protection is afforded the soil by the young legumes at a critical period. In addition, the mucuna bean (*Stizolobium deeringianum*), although valuable for its especially rapid growth, has the disadvantage of tending to climb the coffee trees.

3. *Trenches.* In some cases trenches are dug between the coffee plants and in the paths. These trenches are designed to collect rainfall to be subsequently absorbed by the ground. Those between the plants measure 1·20 m. by 40 cm. by 60 cm., and are situated across the slope ; those in paths and cart-tracks measure 1 metre in length, breadth and depth, and are dug at various intervals, the excavated earth being used to form a bank on the lower side. Such trenches are found to be a hindrance to agricultural operations, and many of the ripening coffee berries fall into them and are lost. Under very heavy rainfall they overflow, the earthen banks are carried off and the trenches have to be remade.

4. *Interlacing.* A system at one time recommended from official sources is the so-called " permanent interlacing," whereby banks of earth and organic matter are constructed along all the paths between the rows of coffee trees, longitudinally and diagonally, so that each coffee plant stands in the centre of its own quadrangle. This system was adopted by many planters, but few retained it for long. One difficulty was the provision of sufficient organic matter for the construction of the banks. A disadvantage was the scraping away of the earth around the coffee plants for the same purpose, leaving the greater part of the ground bare and exposed to the direct action of the sun. What was perhaps the greatest disadvantage was revealed by examination of the coffee plants themselves, when it was found that immediately around the plants absorbent rootlets were rare or non-existent, while they were numerous and superficial in the banks. The coffee plant thus tends to develop an intense network of root hairs that are very superficial and much exposed to the action of prolonged droughts.

5. *Small trenches.* More recently the construction of small contour trenches, approximately 40 cm. in width and 50 to 60 cm. deep, has been tried. Their course in some cases is interrupted on approaching a coffee plant, the ends being closed for the retention of rainfall water ; in other cases it is continuous, winding about among the trees and open at the ends so that the water discharges into the roads or cart-tracks. The edges are approximately level with the surface, excavated earth being deposited as a lateral bank on the lower side, but the spacing between the trenches is arbitrary and unrelated to the type of soil and slope of the ground. With the interrupted type, having the ends closed, spacing must be close in order to avoid overflow, and this makes construction more costly and forms a hindrance to agricultural operations. With the continuous type of trench there is more probability of the water running off, but in the course of the trenches among the coffee plants there are apt to be lower points which act as reservoirs, and the success of the system depends very much on the type of soil and the gradient, for the steeper the land, the greater are the difficulties. In the construction of these trenches, also, insufficient consideration has been given to provision for run-off.

6. *Contour furrows and ridges.* The last system discussed is that of contour furrows and ridges, used principally by planters in the municipality of Jaú. These are distinguished from the contour trenches just described by being flat and wide (approximately 1 metre, whatever the soil or gradient) and by being accompanied by low ridges. Where this system has been used no signs of erosion are to be seen. When ridges have been destroyed at certain points by heavy rainfall, this has been due either to the fact that the extremities of the furrows have been closed up, or—in many cases—that they have received the water of the cart-tracks. Many planters keep their cart-tracks sodded with *Stenotaphrum secundatum* with most satisfactory results, and where this is done there is no overcharging of the contour furrows with run-off from the roads. The position is still better when the contour furrows have their extremities opening into sodded roads or cart-tracks. Illustrations include photographs of cart-tracks sodded with *Stenotaphrum secundatum* and of a run-off canal in which *Paspalum mandiocanum* had just been planted.

The second part of the article, which is not yet completed, is devoted to a detailed description of the method of constructing contour furrows and ridges in a coffee plantation. G. M. ROSEVEARE.

VEGETATION AND EROSION IN MISIONES, ARGENTINA

INTRODUCTION

The Argentine Territory of Misiones is situated between the rivers Uruguay (east) and Alto Paraná (west) and has a central range of hills (average height given as 260 metres) forming a water divide. On account of its topography, the geological origin of the land, the varying depth of its soils, the effect of rainfall and other factors, erosion is bringing about a degradation of the land considered sufficiently important to compromise the whole regional economy unless measures of prevention and control are soon adopted. In order to awaken the public conscience and dispel the general indifference, which is felt to be due in the main to a lack of knowledge, an exposition of the causes and results of erosion in Misiones has been published by Forest Engineer Glieb Gruener, formerly of the Experiment Station of Loreto in the south-west of Misiones, in the *Boletin Estudios y Experimentaciones*, an official publication of the Argentine Ministry of Agriculture, Vol. 6. No. 2. (pp. 1-77). 1941.

TOPOGRAPHY

The landscape of the Territory is hilly, the watercourses numerous, having banks naturally stabilized by tree growth. The banks of the rivers Alto Paraná and Uruguay attain a height of 50 to 100 metres above the watercourses. The steeply sloping banks of these rivers are covered with very dense tree growth, but between the trees and the actual verge of the river there is an almost uniform 30 metre wide strip of *Bambusa Guadua* H.B. which constitutes a perfect natural defence against the carrying off of the banks by rainfall or —to a certain degree—against erosion by the river when in flood. Typical of the territory are stony hills showing the bare rock in places, but having nevertheless covers of humus and organic detritus collected and protected by the hygrophilous forests, themselves characterized by greatly developed undergrowth. The vigorous growth of the vegetation in this humid, sub-tropical region is a weighty factor which almost entirely excludes the possibility of natural erosion in Misiones and can inhibit the phenomenon, once initiated, at the outset.

Erosion in Misiones is thus due to the removal of the plant cover through human activity ; the principal natural factor bringing it about, however, is rainfall.

RAINFALL

In regard to the average annual rainfall three zones are distinguished, running from south to north as follows : the southernmost zone, having an

annual rainfall of 1,400 to 1,600 mm., the largest and intermediate zone, 1,600 to 1,800 mm., and the northernmost, 1,800 to 2,000 mm.

Intensity

Of particular importance is the intensity of the rainfall, expressed in mm. per hour. Unfortunately the meteorological data for the Territory are scanty and there has been no systematic recording. All the information quoted in the present article is derived from the southernmost zone, that of the lowest rainfall, and principally from the Experiment Station of Loreto. The data presented suffice to show, however, the great danger involved in the torrential rains characteristic of the Territory. The following are some of the typical instances.

Posadas.	May, 1928.	120 mm. in 2 hours.
Loreto.	May, 1928.	300 mm. in 11·5 hours, of which 150 mm. fell in the last 2 hours.
Loreto.	May, 1932.	30 mm. in half an hour, causing heavy run-off and a considerable amount of erosion.
Loreto.	January, 1934.	25 mm. in 25 minutes.

The maximum intensity hitherto recorded for Loreto is 75 mm. per hour with a duration of 2 hours. There is reason to assume the existence of still greater intensity in the heavier rainfall zones to the north.

Seasonal distribution. A study of the available data shows that although distribution is irregular within the limits of each year as well as within a period of years, there is nevertheless a more or less regular alternation of two dry seasons with two wet seasons each year. The driest season is that of the summer, having a duration of up to four-and-a-half months (November to March/April), low relative atmospheric humidity and little soil moisture in spite of the fact that the total rainfall for this season exceeds that of the winter dry season. In the winter dry season, on the other hand, which lasts approximately three months (June to September), there is constant soil moisture approaching saturation capacity, and the relative atmospheric humidity, although its average is higher than that of the summer, is prone to abrupt changes.

The wet seasons fall in the autumn (approximately three months, March/April to June) and in the spring (two months, September to November). The early spring rains are gentle, of long duration and of insignificant intensity. The late spring rains and those of the autumn are for the most part torrential; the maximum intensities yet recorded are for the month of May. Such rain as falls in the winter also tends to be of a torrential nature, at least in the beginning of winter.

It is apparent that a large amount of run-off must be produced by torrential autumn rains falling upon a denuded soil almost entirely dried in summer, for in such a case there is a lack of immediate infiltration. In addition the soil particles, loosened through coagulation of the colloids under

high temperature and drought, are readily carried away. In winter and spring infiltration is better, but continued intense precipitation can greatly increase the effects of erosion.

The Dry Seasons

The following description of conditions recorded at Loreto from November 9th to December 11th, 1931, gives a picture of the driest part of the year. During this period there were only four days, November 14th and 15th, 22nd and 23rd, on which rain fell, the quantities recorded being 15, 13, 3 and 11·5 mm. respectively, a total of 42·5 mm. The maximum temperature during the period was 29·4°C., the minimum 15°C., average 23·7°C. The average daily evaporation in the sun was 12·4 mm., total for the period 385·4 mm. The average relative atmospheric humidity was 63·2 per cent.

The winds are found to exercise a marked influence on the dry season; for all the summer winds reduce the relative moisture of the air in direct proportion to their velocity, and whereas in the winter a change in the direction of the wind is productive of rainfall, this is not the case in the summer.

The following figures are given for soil moisture at the end of a dry season, samples being taken on April 6th, 1931, at 3 p.m., from a maté plantation on a three-year-old clearing: (1) from among the fine roots of a dried-up plant of *Digitaria sanguinalis*, 10 to 20 cm. below the surface, 15·69 per cent; (2) harrowed surface, 10 to 20 cm. below the surface, 17·11 per cent.

The Winters

Records made at Loreto in 1931 throw light upon winter conditions in the Territory. There is a period of six months, 6th May to 10th November, during which frosts may occur and a period of two months, 28th June to 31st August, during which long-duration frosts and the lowest temperatures may occur, the absolute minimum recorded being −4·1°C. The frosts generally occur group-wise, each group occupying approximately 6 days, with an interval of about a month between them.

The following succession typifies in general the change of weather in the winter. The hot northern wind, having a maximum velocity of 365 metres per minute, changes to the south wind, which has a maximum velocity of 285 metres per minute. When the wind changes there is rainfall for one or two days, ranging from 15 to 27 mm. The wind holds its direction for 4 or 6 days, dropping at dusk or midnight and being followed by calm, clear nights. At sunrise on the second day after the rain there is frost, which is repeated from two to six consecutive nights with a maximum duration of 6 hours. The minimum temperatures form curves with the depression more or less in the centre of the group of frosts.

The following are examples of the difference between the maximum and minimum temperatures recorded within 24 hours at Loreto, in degrees Centigrade: October 24, 1928, 20·2; December 30, 1928, 20·8; April 2, 1929, 22·2; June 28, 1932, 27·5.

Other Natural Conditions

No systematic scientific studies of the soils of Misiones have yet been made, but, after a discussion of their geological origin, a provisional classification is presented by the author under the following main heads : red soils ; sandy soils ; humus soils ; oropedic, black and brown soils ; acid peat soils ; agropedic soils (applied to the cultivated lands when there is no degradation or erosion) ; skeletal soils. In general, the soils of Misiones have little permeability when dry.

The sand and sand-clay soils are very liable to erosion, and although their total area is not large in Misiones, they are typical and fairly widely distributed. Where forest is cleared from these soils the land degenerates into a xerophilous herbaceous sward, but the soil is more or less bound by the roots of the grasses. The subsequent grazing and burning of these swards, however, very soon leads to disastrous gullying. Where they are used for plantations of maté or other trees, as has been done to a considerable extent, similar damage results.

The soils originating from melaphyre are distributed in all parts of the Territory. They are the lands usually selected for the plantations of maté (*Ilex paraguensis*) which constitute the principal regional culture, and they are more resistant to erosion than the sand soils.

The black alluvial and brown soils are of much value for agriculture and, once drained, are very fertile and good for growing cereals and even, under irrigation, rice, but are not suitable for maté or other tree plantations. Their typical situation in folds and depressions makes them especially liable to erosion through the action of streams and torrents.

Of wide extension and great importance for forestry are the shallow loose red soils and shallow brown soils, the black forest oropedic and the brown oropedic soils, all of which disappear completely from inclinations if cleared of forest and grazed or cultivated, still further increasing the already excessively large area of skeletal soils.

The General Causes of Erosion in Misiones

These may be summed up as the destruction by man of the natural plant communities of the region and the misuse of the lands thus denuded of their primitive vegetation. In this way, the balance between the proportion of rainfall evaporated, retained by the aerial parts of the vegetation, infiltrated into the soil and remaining as superficial run-off has been abruptly changed in favour of the run-off, with well-known results affecting not only the land immediately concerned but the whole network of streams and rivers receiving unduly heavy torrential waters. The process of destruction is cumulative.

Shifting Cultivation

Shifting cultivation in the forests is a serious evil in the Territory and appears to be largely unauthorized, for the nomadic farmers practising it are spoken of as " intruder colonists " and are said to use lands for which they have made no application. The area of virgin forest destroyed is usually out

of all proportion to the amount of land cultivated. A typical case is cited of an " intruder " who in 18 years had cleared 75 hectares of forest, that is to say, over 4 hectares (or 10 acres) per year, in order to plant a little tobacco, a little maize and a few beans on an area hardly amounting to 1 hectare. This particular cultivator, having destroyed all the forest in the immediate vicinity, was proposing to move on to a fresh region to renew his activities. Nomadic colonists are said to be achieving rapid results in the devastation of the Misiones forests and soils, especially in the hills. Where in addition to planting they graze cattle in the semi-destroyed forest, practising burning for the purpose, results are still more serious.

It is estimated that, even with the rapid rate of growth produced by humid, sub-tropical conditions, 25 to 29 years are required for the restoration of forest thus destroyed when there is a soil depth of over 1 metre and practically no beginning of erosion ; but when erosion has begun and the soil is less than 1 metre deep, at least 50 to 60 years are required. Even so, restoration can be effected only if no subsequent erosion is initiated and if the land is protected from burning and grazing. Unless this is done, poor, stony grasslands appear, most aptly described as semi-desert.

Stock-raising and Cultivation

The introduction of stock-raising into Misiones is an important cause of the rapid extension of erosion over large areas, for the region is little suited to this branch of agriculture either by its climate or by the configuration of its land. On the other hand, the infection of the cattle by parasites and the degeneration of the pastures through erosion afford little economic justification for this form of land use. Under the regional conditions, the large-scale creation of meadows and pastures in place of primitive forest is always accompanied by the degradation and impoverishment of the soil.

Cultivation as a cause of erosion is found to be the more serious, the higher the standard of agriculture. Less harm is done by the nomadic cultivators, whose tillage is temporary and superficial only, than by the European settlers whose maté and other plantations are kept carefully tilled and scrupulously clean of weeds. Tillage and weeding, while perfect practices in other regions, are very dangerous under the conditions of Misiones. The large maté plantations are cultivated according to a uniform method, ploughed and harrowed in two directions, whatever the contour of the land, often with devastating effects.

Destruction of Forest

While the destruction of forest plays an important part in the origin of the regional erosion, the ordinary exploitation of sub-tropical forest, namely, the removal of trees of commercial value, is not serious, as enough of the forest elements and especially the undergrowth remain to ensure the conservation of the soil and to regulate run-off. It is the total destruction of forest for grazing and cultivation, shifting or otherwise, which constitutes so grave a menace.

Minor Causes of Erosion

These are found in the practice of grazing woodlands, and in the faulty planning of roads so that in the periods of heavy rainfall these areas are transformed into dangerous torrents, a menace to the neighbouring lands.

Nature and Magnitude of the Damage

(*a*) *Under grazing.* As has already been noted, the most serious erosion is recorded from the sand soils, especially where burning has taken place. In the clay-sand soils, burning and the treading of the animals easily destroys the thin cover of organic debris and humus, and erosion is produced in the form of terraces in bare places. Only certain species of hard tufted grasses and dwarf palms, fairly far apart, resist burning, and between them remain areas composed almost entirely of loose sand, for the clay particles are the first to be washed away. The clay-sands are not so permeable as the pure sands, a fact which promotes surface run-off. The furrows formed by the run-off of rainfall are rapidly transformed into gullies attaining a width of 5 to 7 cm. and a depth of as much as 2 metres. The banks of these narrow canyon-shaped gullies with vertical walls are apt to collapse after a depth of 2 metres has been reached, in directions parallel to the axis of the gully. In this type of land and under the regional grazing practice, erosion begins in land having a slope of 3 per cent and a total run-off width of 100 metres.

In the laterite soils and loose red earths, soil wash at an average rate of 2 cm. per year has been observed near Loreto under regional grazing practice, with an exposure of stones. Erosion is greatly increased in burned localities by the constant movement of animals searching for the more tender shoots of tufts of hard grasses such as *Andropogon paniculatum* Kth., *A. bicornis*, *A. lateralis*, *Axonopus iridaceus* (Mez) Hitchc., *Paspalum quadripharium* Lam., etc. This land has an average depth of 1 metre, with a 9·6 per cent slope and a total run-off width of 75 m. Excessive concentration and movement of animals is recorded. In another place, having loose red alluvial soil, accelerated erosion of the bed of a periodically torrential stream is recorded. This locality was formerly under close tree growth, having springs and streams of permanent or almost permanent character. In these soils lands having slopes of up to 7 per cent with run-off widths not exceeding 100 metres are found to remain intact, but wider slopes tend to produce concentration of rainfall in furrows which are transformed into ramified gullies, and there is a consequent denudation of the substratum at the bottom of the slopes owing to the velocity of the current (3 metres per second).

The brown earths are more permeable but generally shallow and they are situated on impermeable, compact subsoils and solid rock. Some examples are given of damage occasioned through grazing these lands. In Pastoreo Chico and San Ignacio, artificial pastures have taken the place of burnt forest, and in them the disastrous effects of reiterated burning and continuous grazing may be seen in the increasingly large patches of desert land, of bare rock and stone-covered areas. It is estimated that the original forest soil has entirely disappeared within 15 years only. Characteristic of the process is the incipience

of erosion in the rainfall run-off courses, that is to say, in precisely the very place where—under forest protection—the accumulation of alluvial soil would normally take place.

Observations have shown the existence of relations between the width of the run-off area, the percentage of slope and the effect of erosion. The marked effect of occasional burning was demonstrated in a fenced plot at Loreto, as a rule neither burned nor grazed, having soil of the oropedic type, a sward composed of tufts of hard grasses (*Paspalum quadripharium, Axonopus iridaceus*) and *Baccharis dracunculifolia*, a 9 per cent slope and a run-off width of 40 metres. It was burned once, and 12 hours after the fire a rainfall of 34.5 mm. ensued on November 24th, 1933, normally insufficient to produce any marked degree of run-off under the same natural conditions. In this case, however, a layer of earth having an average thickness of 1 centimetre was completely carried away, together with all the ash.

In another plot at Loreto with brown forest soil of 1 metre and more in depth, a 9 per cent slope and run-off width of 60 metres, no actual soil wash has occurred although vestiges of incipient erosion, stopped at the outset, may be distinguished in the appearance of small stones and in rainfall furrows. This plot had been ploughed and planted with *Pennisetum purpureum* 10 years before and consistently grazed afterwards, but never overstocked or burned. The elephant grass, under the influence of grazing, disappeared within four years and was replaced by hard grasses in isolated tufts with a low herbaceous sward between them and *Baccharis dracunculifolia* as an upper growth.

At Loreto also a section of campo having oropedic soil, a 36·4 per cent slope and a run-off width of 50 metres, continuously burned and grazed, exhibits tufts of hard grasses and also *Erianthus Trinii* Nees and *Sporobolus elongatus* Rbr. growing in earthen banks up to 30 cm. high that are fixed by the grass roots, the soil to this depth about the banks having been washed away during a period of unknown duration.

Indubitable signs of erosion—the appearance of medium-sized and large stones over the whole surface—are apparent at Loreto on oropedic soil with a 21·6 per cent slope and a total run-off width of 100 metres when there is burning and grazing. At the same time, a soil of less than one metre in depth, in part oropedic, on a 3·5 per cent slope, substratum only slightly permeable and run-off width of 100 metres, reveals no marked signs of erosion. It is covered by stoloniferous grasses (*Arachis prostrata, Axonopus compressus, Paspalum notatum*) and is grazed, but not burned. Erosion begins with a run-off width of 120 metres.

Observations on the whole lead to the conclusion that, under pastoral conditions, erosion begins to be marked in the brown forest soils on slopes of 5 per cent upwards and with 100 metres run-off width. On steeper slopes the formation of rainfall run-off canals is observed. The most serious losses on these inclined soils are incurred in the first few years of burning and grazing, soils on slopes of up to 10 per cent losing annually an average of at least 2 centimetres of the fertile, humus cover.

(*b*) *Under annual crops.* The following are some examples of damage observed. At Eldorado, in loose red soil, an average of 7 cm. for the whole surface was carried off within 4 years from an area that had been deforested, and there were gullies having a depth of as much as 26 cm. At the present time, furrows 8 cm. deep develop in one year. The trouble is attributed to intensive cultivation, especially with the disc harrow: the crops grown are maize, tobacco and *Vigna catjang*, the last-named disked in after the harvesting of the pods.

In another part recently burned clearings on loose red soil exhibit in some places gullies up to 20 cm. deep on a slope of 7 per cent. and a run-off width of 200 metres. Under the same conditions, but where the forest has been cleared only and not burned, the degree of erosion is much less.

It is found that in permeable soil deep ploughing can diminish erosion, while superficial scratching accelerates it, especially in the case of the more compact soils. The season at which tilling is done and the character of the rainfall are naturally of importance. Another practice promoting surface erosion is the systematic burning of dry weeds.

In the case of annual crops, erosion begins to be apparent in sandy soils when the run-off width is 100 metres and there is a slope of over 2 per cent, in the brown forest soils over 4 per cent, and in loose red soils and laterites over 5 per cent.

(*c*) *Under plantations of trees, maté in particular.* Here again the most disastrous erosion is found in the sandy soils. There is recorded a case at Loreto of a young maté plantation on soil of this type, with an 8·8 per cent slope and a run-off width of 120 metres, ploughed and harrowed intensively, which lost in a period of 8 months (August to April) a minimum of soil 2 cm. deep through sheet erosion, while furrows and cavities were produced by rainfall. This maté stand had just been planted to replace another of 3 to 4-year-old trees which had been completely washed away together with the soil. On the property in question under similar conditions, even where the trees have not been washed away or replaced, the average annual loss of soil is estimated at 2·5 cm.

Under the regional intensive form of cultivation the erosion of such soils begins to be apparent when there is a slope of 2 per cent and 100 metres run-off width. The brown earths are more readily deprived of the surface layer and are less resistant to the action of erosion than the red earths and laterites, as is seen especially in the case of the shallower soils with imperfect permeability in the substratum. On the other hand, these soils exhibit greater infiltration and absorption capacity when dry.

The following examples of erosion in the brown earths are described. Loss of humus cover to an average depth of 25 cm. within a period of 21 years is recorded for a maté plantation on shallow brown forest soil with a fairly permeable subsoil. The locality is in a river valley, its peculiarity being that it forms a kind of ridge favouring run-off on both sides and impeding the concentration of rainfall. In this plantation sweet potatoes are planted and harrowed.

A fifteen-year old maté plantation at Loreto on brown forest soil of 1 metre and more in depth has been left for 10 years without being ploughed in the direction of the maximum slope. Seven years ago this plantation was eliminated from the list of productive plantations on account of the complete degradation of the eroded parts of the area, and for the last few years it has been used as a grazing ground. Such maté plants as have not died exhibit signs of advancing decay or are stunted, and the area has become invaded by *Baccharis* and *Andropogon paniculatum*, *Paspalum notatum* and *Axonopus compressus*, grasses which gradually fix the soil. There has been, however, an entire removal of the surface soil layer, the appearance of stones, the baring of large areas of rock and subsoil, and the formation of gullies in the direction of the maximum slope. It is concluded that, in general, maté cannot be intensively cultivated in brown forest soil when there is more than a 4 per cent slope and a run-off width of 100 metres, without incurring the risk of active erosion.

The loose red earths are less resistant to the mechanical action of erosion than the laterites, especially in the case of the shallow soils, but on the other hand they are more permeable. These two categories of red soils are therefore considered as approximately equal in their degree of erodibility. The following are some of the examples given of erosion in the red earths.

A large maté plantation at Candelaria has been uniformly cultivated in a direction more or less at right angles to the maximum slope, and the rows of trees are arranged without reference to contour. Although hilling of the trees has been adopted and crude transverse dams made of stakes and planks with heaped cut branches and weeds have been built across furrows and gullies, the erosion continues. The soil is over 1 metre deep, there is a maximum slope of 5.3 per cent and a run-off width of 300 metres. Cavities 1·10 metres deep, not yet consolidated, are typical.

In a large 12-year-old maté plantation at San Ignacio, located on loose red over 1 metre deep, the average removal of the soil cover is estimated as soil 1 cm. per year for 12 years, and the former rainfall run-off ducts have become transformed into gullies over 1 metre deep. In these gullies soil wash is much greater. The maté trees die in very large numbers, but are replaced. In many places the bare rock has become exposed. A large maté plantation at Posadas on laterite soil with a 9·63 per cent slope and a run-off width of 60 metres is estimated to lose an average of 3 cm. soil per year through erosion, and the roots of the maté trees have become exposed.

It is concluded that in the red soils under intensive cultivation, with a run-off width of 100 metres, accelerated erosion may be expected from a slope of 2 to 3 per cent upwards, but if contour ploughing plus harrowing are practised, erosion will not occur until there is a slope of 4·5 to 5 per cent.

Sown Grasslands

Entire approbation is expressed of the management of certain so-called artificial grasslands maintained by European colonists of Eldorado and other places for their own domestic animals. These meadows and pastures fix

the soil, are well managed, neither burned nor overstocked, and occupy only such areas as are strictly necessary. Grasses are sown or planted by means of slips, tillering species being chosen for preference. Of the grasses used, the following—indigenous in Misiones and the neighbouring regions—are mentioned: *Axonopus compressus*, *Cynodon dactylon*, *Paspalum dilatatum*, *P. notatum*, and *Stenotaphrum glabrum* together with its form *erecta*.

G. M. ROSEVEARE.

THE AGRICULTURE OF SZECHWAN

The Province of Szechwan, in which the wartime capital of China, Chungking, is situated, has an important role in the interior economy of western China under war conditions. Dr. H. L. Richardson, formerly of Victoria University College, Wellington, New Zealand, and Rothamsted Experimental Station, has published an account of the climate, geology, soils and land utilization of the Province, based upon a Report of a tour made in many regions of Szechwan in 1938 ("Soils and agriculture of Szechwan," published by the National Agricultural Research Bureau, Ministry of Agriculture and Forestry, Chungking, June, 1942, Special Publication No. 27).

An interesting feature of the Province is the well-marked "vertical zonation" of climate, vegetation and soils which may be observed between low and high altitudes; Richardson quotes Wilson's classification into seven zones as regards climate and vegetation as follows:

"(1) *Warm temperate zone* (below 2,000 ft., 600 m.): the "belt of cultivation," with bamboos, palms, cypress, pine, tung oil, oranges, vegetable tallow, insect white wax, as typical trees; rice, cotton, sugar cane, maize, tobacco, sweet potatoes and legumes as summer crops; and wheat, rape seed, cabbage, Irish potatoes, legumes, and hemp as winter crops.

(2) *Temperate zone* (2,000-5,000 ft., 600-1,500 m.): the "evergreen rain forest" belt, with evergreen oaks, *Castanopsis*, Lauraceae, holly, pines, *Cunninghamia*, and ferns. Cultivation is still common, the chief crops being similar to the previous zone, but maize displaces rice as chief food crop and winter crops are less important. The upper limit of rice cultivation is around 4,000 ft. (1,200 m.). Tea is grown.

(3) *Cool temperate zone* (5,000 to 10,000 ft., 1,500 to 3,000 m.): chiefly deciduous, flowering trees and shrubs, of genera familiar in North America and Europe; also rhododendrons, conifers, tall herbs and flowering plants. The chief crops are wheat, maize, and Irish potato, the upper limit of maize cultivation being about 8,500 ft. (2,500 m.). Walnut and varnish trees are common. Towards the upper limit of the zone, forests of conifers are found.

(4) *Sub-alpine zone* (10,000 to 11,500 ft., 3,000 to 3,500 m.): A narrow transition belt, mostly moorland, with dwarf bamboo and scrubby shrubs (especially rhododendrons); some large coniferous forests (larch, spruce, and silver fir). Wheat and barley are the crops grown. (Note by the writer: also Irish potatoes.)

(5) *Alpine zone* (11,500 to 16,000 ft., 3,500 to 4,800 m.). The limit of tree growth, and also of wheat and barley, is around 12,000 ft. (3,600 m.); of woody scrub, around 15,500 ft. (4,600 m.); so that this zone is mostly occupied by herbs, many with intensely coloured flowers, and by grasses. Meadows, heaths and moorlands occur. Rhubarb and other medicines are grown.

(6) *High alpine zone* (16,000 to 17,500 ft., 4,800 to 5,200 m.). Glaciers and moraines and alpine deserts occur; the limit of vegetation is around 16,500 ft. (5,000 m.), cushion plants and herbs being the highest plants.

(7) *Perpetual snow* (above 17,500 ft. or 5,200 m.; Minya Konka, in Sikang, is 24,900 ft., or 7,600 m.). The high level of the snow-line is attributed to the dryness of the climate at these altitudes."

The whole Province of Szechwan is drained by the Yangtze Kiang and its tributaries. These rivers are important for transport, especially within the Red Basin. The Province is roughly triangular in shape, with mountain ranges on all sides; it is therefore lower in the middle than at the edges, and, since the hollow ground in the centre consists of purplish-red rocks, geographers have named it the Red Basin of Szechwan.

The dimensions of the Province are some 800 km. from east to west and rather less from north to south. Its human population is estimated at from 50 to 70 million of which 10 per cent lives in cities, the remainder being directly or indirectly supported by agriculture. The Province is thus similar to Germany in size and population, but very different in the proportion of people on the land and in the average poverty of the inhabitants.

Richardson discusses climate with particular reference to temperature and rainfall, noting in connexion with rainfall that the data are much more complex than for temperature, and that rainfall has an overruling influence on land utilization and crop production, too much or too little being equally likely to cause a famine. A generalized rainfall map of Szechwan divides the country into zones with mean annual rainfalls varying from under 800 mm. to over 1,400 mm. Much of the rain falls as sudden violent rainstorms, which do little good due to lack of infiltration into the soil, and may do much harm by accelerating local erosion and causing the flooding of streams and rivers. The rich, muddy colour of the main rivers in the rainy season supplies evidence of the amount of fine fertile soil that is eroded and lost each year in the flood waters.

In 1938 rice occupied about 51 per cent of the total crop area; sweet potatoes are the second summer crop in the province, maize the third; other summer crops follow in descending order: beans, kaoliang, cotton and sugar-cane. Minor summer crops, none of which occupy as much as 1 per cent of the total cultivated area, are peanuts, buckwheat, potatoes, sesame, medicinal plants, tobacco and hemp.

Winter crops include wheat (18·6 per cent of the cultivated land in 1929-33), barley, rapeseed, field peas and broad beans. Minor winter crops

include *Astragalus sinensis* and vetch. Sections of the publication are also devoted to tree fruits, vegetable and garden crops, and economic trees and shrubs.

Pastures are practically absent from most of the Province, the nearest approach to grassland being in the form of grassed gravelands, or rare grassy hillsides that are grazed by goats, bullocks or buffaloes. In the far west and northwest of the Province, however, grazing lands are reported to be plentiful. There is general agreement that the grasslands of northwest Szechwan are an extension of those of the Northern Tibetan plateau. The grassland in this region is grazed by nomadic tribes who keep flocks or herds of yaks, sheep and goats. The interior tribes, notably the Goloks, are extremely lawless and dangerous, so much so that the country is practically unexplored away from the trade routes.

Richardson considers that the problem of developing that part of this grassland region that falls within the Province of Szechwan as a source of butter, wool, skins and meat is one deserving full attention. Because of the high altitude, short growing season and low rainfall, extensive resettlement and arable cultivation are unlikely to succeed. The problem is rather one of pacifying and stabilizing the present population and introducing improved breeds and methods of animal and grassland husbandry, as well as better methods of production.

Although Szechwan is an agricultural Province, with very little pastoral land except the area in the north-west just discussed, it has quite a high animal population. Of the ten million and more head of animals (excluding poultry), about one-half are work animals (water buffaloes and oxen) and the other half productive animals (chiefly pigs, goats and sheep). In the absence of extensive areas of grazing lands, these animals are fed largely on farm by-products (straw, weeds, broad bean leaves, vetch, etc.) and on crops grown for the purpose (barley); a little rough grazing is found on field dykes and terrace edges, gravelands and waste lands.

Richardson devotes a large section of his publication to the conservation of soil and water, noting that the principles are the same as elsewhere, but that the actual practices that will be applicable in the Province will have to be found from experience. Erosion appears to be a more serious practical problem in the hills and mountains around the Red Basin than in the Basin itself.—R. O. WHYTE.

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